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EMISSIONS AND AIR QUALITY IMPACTS OF NESHAP FOR INDUSTRIAL, COMMERCIAL, AND INSTITUTIONAL BOILERS AND PROCESS HEATERS

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DISCLAIMER

This document was developed to provide technical support for the Regulatory Impact Analysis prepared by EPA professional staff. The analysis and conclusions presented in this report are those of the authors and should not be interpreted as necessarily reflecting the official policies of the U.S. EPA. This document was developed to derive national air quality impacts for this rule. However, while useful to derive national impacts estimates, information associated with any given county or area are subject to significant uncertainties and should not be used to predict the cost or benefits that may result in a specific county or area.

CONTENTS

TABLES

ACRONYMS AND ABBREVIATIONS

BOA	biogenic organic aerosol
cm/s	centimeters per second
CO	carbon monoxide
CRDM	Climatological Regional Dispersion Model
dv	deciview
EC	elemental carbon
EFIG	Emission Factor and Inventory Group
EPA	U.S. Environmental Protection Agency
FAC	fractional aerosol coefficients
HAPs	hazardous air pollutants
ICCR	Industrial Combustion Coordinated Rulemaking
ISC2LT	Industrial Source Complex Long Term model
km	kilometers
Latimer	Latimer & Associates
LRM	Lagrangian Regional Model
m agl	meters above ground level
m/s	meters per second
MACT	maximum achievable control technology
mh	mixing height
MMBtu	million British thermal units per hour
NAAQS	National Ambient Air Quality Standards
NCDC	National Climatic Data Center
NESHAP	national emissions standard for hazardous air pollutants
NET	National Emissions Trends
NH_3	ammonia
nm	nanometers
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
NPI	National Particulates Inventory
Pechan	E.H. Pechan & Associates, Inc.
PM	particulate matter
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 micrometers
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 micrometers
ppbv	parts per billion by volume
rh	relative humidity
RH	regional haze
S-R	source-receptor
SCC	Source Classification Code
SO_2	sulfur dioxide
SOA	secondary organic aerosols
SSD	summer season daily
VOC	volatile organic compounds

CHAPTER I
INTRODUCTION AND OVERVIEW

The U.S. Environmental Protection Agency (EPA) is currently working on a proposal of a rule to reduce the emissions of hazardous air pollutants (HAP) from industrial, commercial, and institutional boilers (henceforth referred to as "industrial") and process heaters in the United States. Proposal of this rule is scheduled for early in 2001. This proposed national emissions standard for hazardous air pollutants (NESHAP) will reduce emissions of arsenic, beryllium, benzene, and many other HAP's. These standards will also reduce emissions of non-HAP species such as particulate matter and sulfur dioxide (SO_2).

The analyses presented in this report provide an assessment of the emissions and air quality impacts associated with EPA's proposal to impose emission limits on industrial boiler and process heater sources under NESHAP. Specifically, this report addresses the impacts of reducing primary particulate matter with an aerodynamic diameter less than or equal to 10 micrometers and 2.5 micrometers (PM_{10} and $PM_{2.5}$), and SO_2 emissions from industrial boilers and process heaters and their effect on ambient concentrations of particulate matter (PM) and regional haze (RH).

Air quality benefits are provided for two control scenarios: (1) floor-level maximum achievable control technology (MACT) and (2) above-the-floor MACT.[1] The floor-level MACT affects existing and new boilers and process heaters that have input capacities greater than 10 million British thermal units per hour (MMBtu/hr) and do not use a liquid fuel as their primary fuel type. The above-the-floor MACT will affect the same units as the floor-level scenario, in addition to units that use residual oil as a primary fuel. The PM and SO_2 emission reductions for the two control scenarios were provided to E.H. Pechan & Associates, Inc. (Pechan) by EPA and are not discussed in this report in detail.

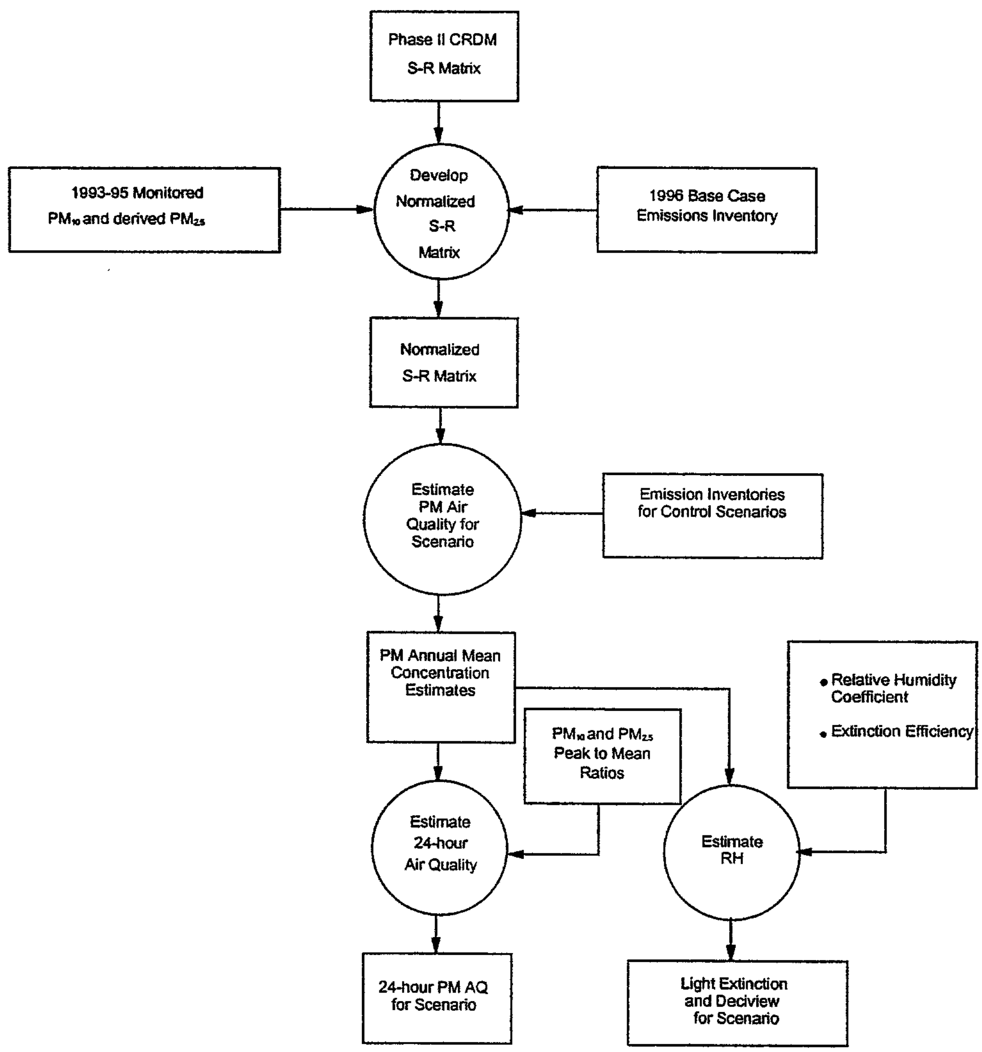
The emissions inventories used to conduct this analysis are the 1996 National Emissions Trends (NET) Inventory, Version 3.12 (EPA, 2000) and the Industrial Combustion Coordinated Rulemaking (ICCR) inventory. The ICCR inventory provided by EPA on January 30, 2001, was used to supply baseline emissions and reductions for industrial boiler and process heater PM and SO_2 emissions. The nitrogen oxides (NO_x) and volatile organic compounds (VOC) emissions from industrial boiler and process heater sources, and for all pollutants from other emission sectors (area, non-road, and mobile sources) were obtained from the 1996 NET Inventory. Thus, the inventory developed and used in this analysis is a hybrid of the two national emission inventories.

[1]The above-the-floor option examined in the report provides greater PM and SO_2 emission reductions than those for the MACT floor alternative. This is also called option 1A. Option 1B is a second above-the-floor in which additional monitoring and recordkeeping requirements are applied, but lead to no additional emission reductions beyond those in option 1A. Therefore, no air quality modeling for option 1B is done for this report.

PM and RH air quality were examined by applying the Phase II source-receptor (S-R) matrix developed with the Climatological Regional Dispersion Model (CRDM) to the baseline and control scenarios. The same methodology was utilized in the analysis of PM alternatives in support of revisions to the National Ambient Air Quality Standards (NAAQS) (Pechan, 1997) and the proposed Heavy-Duty Diesel Rule (Pechan, 2000). Methods for assessing the RH changes are those utilized in the analysis of alternative RH goals for the RH Rule (Pechan, 1998).

Chapter II of this report provides a summary of the emissions inputs used to estimate changes in air quality. Chapters III and IV document the methodologies used to estimate PM air quality and RH, respectively. Results are summarized within these chapters as well. An overview of the methodology is illustrated in Figure I-1.

Figure I-1
Overview of Methodology



CHAPTER II
DEVELOPMENT OF EMISSION ESTIMATES

This Chapter describes the development of the 1996 Base Case and Control scenarios used in this analysis. Two national criteria pollutant emission inventories were used to develop the Base Case and control scenarios: the 1996 NET Inventory, Version 3.12 (EPA, 2000) and the ICCR inventory (ERG, 2001). The ICCR inventory was used to supply industrial boiler and process heater PM and SO_2 emissions. The 1996 NET was the source of VOC, secondary organic aerosols (SOA) and NO_x emissions for industrial boiler and process heater sources, and for all pollutants from other emission sectors (other point sources, area sources, non-road sources, and mobile sources).

A. MAIN ANALYSES

1. Base Case

a. Industrial Boiler and Process Heater SO_2 and PM_{10} Emissions

Annual emissions of PM_{10} and SO_2 from industrial, commercial, and institutional boilers (henceforth referred to as "industrial") and process heaters in the United States were supplied to Pechan by EPA. The source of these emission estimates is the ICCR Inventory. This inventory contains emission estimates of sources most often at the state-county-facility-fuel type level. $PM_{2.5}$ emission estimates were added to this inventory using the PM Calculator developed by Pechan for the Emission Factor and Inventory Group (EFIG) of EPA. The PM Calculator allows $PM_{2.5}$ emissions to be estimated by linking (by Source Classification Code [SCC]) fractional aerosol coefficients (FAC) to known PM_{10} emission levels. Organic carbon and elemental carbon were also added to the inventory for these sources using FACs linked by SCC.

b. Other Emission Inputs

NO_x, VOC, and SOA emissions from industrial boiler and process heater sources, and for all pollutants from the other emission sources (other point sources, area sources, non-road sources, and mobile sources) were obtained from the 1996 NET Inventory. This inventory consist of separate files for point, on-highway mobile, stationary area, and nonroad sources. The files contain annual and summer season daily (SSD) emissions for the following pollutants: NO_x, VOC, carbon monoxide (CO), SO_2, PM_{10} and $PM_{2.5}$, ammonia (NH_3), and SOA.

2. Control Scenarios

Emission inventories were developed for two control scenarios: (1) floor-level MACT and (2) above-the-floor MACT. The floor-level MACT affects existing and new boilers and process heaters that have input capacity greater than 10 MMBtu/hr and do not use a liquid fuel as their primary fuel type. The above-the-floor MACT will affect the same units as the floor-level scenario, in addition to units that use residual oil as a primary fuel. The control scenarios incorporate reductions in PM (both PM_{10} and $PM_{2.5}$) and SO_2 only - i.e., NO_x and VOC emissions are identical to those in the Base Case. The PM and SO_2 emission reductions for the two control scenarios were provided to Pechan by EPA. Tables II-1 and II-2 provide a summary of the Base Case PM_{10} and SO_2 emissions and control scenario reductions for industrial boilers and process heater sources. These are the emission estimates contained in the ICCR inventory.

B. SENSITIVITY ANALYSES

Four sensitivity analyses were performed to determine the independent effect of PM and SO_2 controls on air quality. Since the NESHAP control scenarios provided both PM and SO_2 emission reductions, the sensitivity analyses examined PM and RH air quality assuming (a) SO_2 controls alone and (b) PM controls alone for the floor-level MACT and above-the-floor MACT scenarios.

Table II-3 provides a summary of the national emissions for the 1996 Base Case and the two control scenarios by sector.

The PM and SO_2 Base Case emissions and emission reductions listed in Tables II-1 through II-3 are only for units that are mapped to a specific control device. There are other reductions of PM and SO_2 attributable to this proposed regulation that are not included in these tables, for these reductions are from units for which no specific control device has been assigned. Since it is not possible to link actual emission reductions to specific units, these emission reductions cannot be input to the air quality model. Nationally, the reductions included in the air quality modeling compose roughly half of the estimated PM and SO_2 reductions attributable to this proposed regulation.

Table II-1

Summary OF ICCR Industrial, Commercial and Institutional Boiler Emissions and Control Scenario Reductions by State (tons/year)

State	PM_{10} Emissions ICCR Base	PM_{10} Reductions Floor-Level MACT	PM_{10} Reductions Above-the-Floor MACT	SO_2 Emissions ICCR Base	SO_2 Reductions Floor-Level MACT	SO_2 Reductions Above-the-Floor MACT
Alabama	18,473	17,576	17,814	22,557	0	0
Arizona	0	0	0	0	0	0
Arkansas	809	0	580	0	0	0
California	164	0	33	0	0	0
Colorado	2,338	2,176	2,176	7,935	606	707
Connecticut	168	0	70	0	0	0
Delaware	15	0	0	0	0	0
DC	4,707	3,639	3,728	63,221	0	0
Florida	21,747	0	496	0	0	0
Georgia	9,578	7,501	8,206	62,541	5,153	5,153
Idaho	0	0	0	0	0	0
Illinois	947	825	825	4,659	0	0
Indiana	9,782	8,869	9,006	26,885	3,031	4,243
Iowa	5,761	4,213	4,213	89,903	3,031	6,629
Kansas	844	0	217	15,239	0	0
Kentucky	1,241	955	955	14,165	606	606
Louisiana	68,320	45,652	52,058	82,228	0	0
Maine	8,027	888	6,155	1,137	0	0
Maryland	1,876	1,820	1,820	2,329	0	0
Massachusetts	21,257	15,479	19,072	32,014	303	303
Michigan	29,985	23,298	23,951	269,856	19,752	25,043
Minnesota	4,431	2,027	2,185	156,643	13,875	14,765
Mississippi	2	0	0	0	0	0
Missouri	2	0	0	0	0	0
Montana	0	0	0	0	0	0
Nebraska	3,809	3,545	3,545	9,780	303	303
Nevada	1	0	0	0	0	0
New Hampshire	1,084	0	796	0	0	0
New Jersey	2,530	0	1,549	0	0	0
New Mexico	30	0	11	56	0	0
New York	10,882	9,955	10,343	12,966	0	107
North Carolina	32,238	26,896	28,891	134,859	6,163	6,213
North Dakota	3,630	3,193	3,193	21,132	1,515	1,689
Ohio	3,659	2,339	2,358	80,519	7,897	8,001
Oklahoma	3,564	2,729	2,729	50,600	640	640
Oregon	0	0	0	0	0	0
Pennsylvania	28,114	22,235	23,164	309,922	2,425	2,478
Rhode Island	410	0	301	0	0	0
South Carolina	16,202	11,634	13,181	126,997	3,132	3,239
South Dakota	3,135	3,003	3,003	6,286	909	909
Tennessee	33,347	29,615	30,204	153,532	2,829	2,829
Texas	573	0	0	7,928	0	0
Utah	1	0	0	0	0	0
Vermont	603	0	435	28	0	0
Virginia	12,031	3,747	6,930	257,435	5,186	6,065
Washington	8,493	8,188	8,194	13,162	1,212	1,212
West Virginia	420	296	311	6,216	606	606
Wisconsin	3,716	2,863	2,946	30,835	2,122	2,374
Wyoming	840	0	0	53,378	1,246	1,246
Total	**379,792**	**265,155**	**295,645**	**2,126,945**	**82,542**	**95,361**

Table II-2
Summary OF ICCR Process Heater Emissions and Control Scenario Reductions by State
(tons/year)

State	PM_{10} Emissions ICCR Base	PM_{10} Reductions Floor-Level MACT	PM_{10} Reductions Above-the-Floor MACT	SO_2 Emissions ICCR Base	SO_2 Reductions Floor-Level MACT	SO_2 Reductions Above-the-Floor MACT
Alabama	1,851	0	1,385	0	0	0
Arizona	1	0	0	0	0	0
Arkansas	0	0	0	0	0	0
California	399	0	219	0	0	0
Colorado	1	0	0	0	0	0
Connecticut	0	0	0	0	0	0
Delaware	1	0	0	0	0	0
Florida	520	0	272	0	0	0
Georgia	0	0	0	0	0	0
Idaho	0	0	0	0	0	0
Illinois	0	0	0	0	0	0
Indiana	103	0	60	0	0	0
Iowa	0	0	0	0	0	0
Kansas	2,713	0	2,031	0	0	0
Kentucky	0	0	0	0	0	0
Louisiana	14,724	0	10,144	0	0	0
Maine	0	0	0	0	0	0
Maryland	0	0	0	0	0	0
Massachusetts	52	0	38	0	0	0
Michigan	1,552	0	1,119	0	0	0
Minnesota	882	0	660	0	0	0
Mississippi	0	0	0	0	0	0
Missouri	1	0	0	0	0	0
Montana	3	0	0	0	0	0
Nebraska	120	0	76	0	0	0
Nevada	0	0	0	0	0	0
New Hampshire	0	0	0	0	0	0
New Jersey	2	0	0	0	0	0
New Mexico	26	0	0	0	0	0
New York	0	0	0	0	0	0
North Carolina	384	0	288	0	0	0
North Dakota	239	0	177	0	0	0
Ohio	0	0	0	0	0	0
Oklahoma	687	0	477	0	0	0
Oregon	0	0	0	0	0	0
Pennsylvania	465	0	348	0	0	0
Rhode Island	0	0	0	0	0	0
South Carolina	542	0	400	0	0	0
Tennessee	618	0	455	0	0	0
Texas	374	0	0	0	0	0
Utah	0	0	0	0	0	0
Vermont	0	0	0	0	0	0
Virginia	204	0	153	0	0	0
Washington	0	0	0	0	0	0
West Virginia	4	0	0	0	0	0
Wisconsin	14	0	0	0	0	0
Wyoming	0	0	0	0	0	0
Total	**26,481**	**0**	**18,302**	**0**	**0**	**0**

Table II-3

Summary of National Emissions for Base Case Scenario, Floor-Level MACT and Above-the Floor MACT Control Scenarios by Sector
(tons/year)

Pollutant	Source Type	1996 Base Case Scenario Emissions	Floor-Level MACT Control Scenario		Above-the-Floor MACT Control Scenario	
			Emissions	Reductions[a]	Emissions	Reductions[a]
VOC	Point	2,176,074	2,176,074	-	2,176,074	-
	Area	8,204,456	8,204,456	-	8,204,456	-
	Motor Vehicle	4,900,419	4,900,419	-	4,900,419	-
	Nonroad	3,241,089	3,241,089	-	3,241,089	-
	Totalb	**18,522,037**	**18,522,037**	**-**	**18,522,037**	**-**
NOx	Point	9,184,393	9,184,393	-	9,184,393	-
	Area	2,420,821	2,420,821	-	2,420,821	-
	Motor Vehicle	9,392,191	9,392,191	-	9,392,191	-
	Nonroad	5,119,930	5,119,930	-	5,119,930	-
	Total	**26,117,335**	**26,117,335**	**-**	**26,117,335**	**-**
CO	Point	5,356,707	5,356,707	-	5,356,707	-
	Area	15,167,469	15,167,469	-	15,167,469	-
	Motor Vehicle	53,585,364	53,585,364	-	53,585,364	-
	Nonroad	24,527,607	24,527,607	-	24,527,607	-
	Total	**98,637,147**	**98,637,147**	**-**	**98,637,147**	**-**
SO2	Point	3,961,889	3,879,347	82,542	3,866,528	95,361
	Area	1,397,425	1,397,425	-	1,397,425	-
	Motor Vehicle	302,938	302,938	-	302,938	-
	Nonroad	840,167	840,167	-	840,167	-
	Total	**6,502,418**	**6,419,876**	**82,542**	**6,407,058**	**95,361**
PM10	Point	1,167,995	902,839	265,155	854,048	313,947
	Area	30,771,607	30,771,607	-	30,771,607	-
	Motor Vehicle	294,764	294,764	-	294,764	-
	Nonroad	463,579	463,579	-	463,579	-
	Total	**32,697,944**	**32,432,789**	**265,155**	**32,383,997**	**313,947**
PM2.5	Point	576,022	500,928	75,095	481,457	94,565
	Area	6,675,777	6,675,777	-	6,675,777	-
	Motor Vehicle	230,684	230,684	-	230,684	-
	Nonroad	410,334	410,334	-	410,334	-
	Total	**7,892,816**	**7,817,721**	**75,095**	**7,798,251**	**94,565**
NH3	Point	248,887	248,887	-	248,887	-
	Area	4,275,947	4,275,947	-	4,275,947	-
	Motor Vehicle	228,312	228,312	-	228,312	-
	Nonroad	9,170	9,170	-	9,170	-
	Total	**4,762,317**	**4,762,317**	**-**	**4,762,317**	**-**

NOTES: [a]Reductions are Base Case Emissions minus Control Case Scenario Emissions.
[b]The totals reflect emissions for the 48 contiguous States, excluding Alaska and Hawaii.

CHAPTER III
PM AIR QUALITY

The criteria pollutant emissions for the Base Case and control scenarios were used to estimate PM air quality. The method utilizes a S-R matrix to convert emissions to ambient pollutant concentrations using methodologies developed by Pechan in support of the recent Particulate Matter, Ozone, and Regional Haze NAAQS analysis (Pechan, 1997). The difference between the control scenario and the Base Case PM levels represents the expected air quality benefit of implementing the NESHAP for industrial boilers and process heaters. The outputs include annual average concentrations of primary PM_{10} and primary $PM_{2.5}$, nitrate, sulfate, NH_3, particulate biogenic organic aerosol (BOA), and SOA. Twenty-four-hour peak concentrations of PM_{10} and $PM_{2.5}$ are also estimated.

A. DEVELOPMENT OF THE U.S. PM S-R MATRIX

A regional dispersion model was applied to a 1990 U.S. national emission inventory to estimate ambient concentrations throughout North America. Version 3 of the National Particulates Inventory (NPI) (Pechan, 1996) was selected as the base year inventory since it covers the 48 contiguous States and provides a consistent data set for all of the precursors leading to the formation of ozone and PM. A S-R matrix, relating emissions from a source to a concentration at a receptor county, was then developed based on this air quality modeling. This section describes the development of the regional dispersion model and summarizes a comparison of the modeled concentrations to monitored values. This dispersion-modeling was conducted by Latimer & Associates (Latimer) and is described below.

Latimer applied a regional dispersion model to estimate ambient PM concentrations in the 48-contiguous States. The Lagrangian Regional Model (LRM) was applied to one emission source. Because of the extensive computer requirements, it was not possible within the timeframe of the air quality modeling project to apply the LRM to all of the nearly 6,000 sources in the United States. Thus, the limited LRM results were used to guide the adjustment of the CRDM that was developed during the first phase of the work. The adjusted CRDM was applied to calculate a transfer matrix of S-R relationships for all relevant emissions and chemical species and to calculate cumulative regional ambient concentrations of $PM_{2.5}$ and PM_{10} as well as important chemical constituents including sulfate, nitrate, and secondary organics. The modified CRDM, when used with greatly scaled down primary PM emissions, provides comparable estimates of the spatial distribution of annual concentrations in the United States.

1. Lagrangian Regional Model (LRM)

A LRM approach was developed that calculates the transport, diffusion, deposition, and chemical conversion of emissions using a spatially and temporally varying wind field. The North American wind field was provided by EPA based on mesoscale model calculations carried out in 1994 for the meteorology of 1990. These data were reduced by Latimer to a smaller input file by calculating mixing height and average winds and relative humidities in the mixed layer.

The LRM was tested for a single point source using a few days of data. LRM is based on simple dispersion, deposition, and chemical conversion concepts used in HAZEPUFF (Latimer, 1993). Puffs are released hourly and transported by the averaged winds appropriate for the time and location of the puff. A single uniform concentration for each hourly puff is calculated by expanding the puff box using standard Pasquill-Gifford Δ_z values, limited by the mixed layer height, and mesoscale Δ_y values from Gifford (1982). Deposition is handled using deposition velocities applied to the ground-level concentrations. Sulfur oxidation is calculated at a rate that depends on relative humidity (rh) ranging from 0.5 percent/hour for rh<40 percent to 1.5 percent/hour for rh>70 percent. Nitrogen oxidation was assumed to take place at 2 percent/hour.

The LRM was successfully applied to a single source; however, the computer memory and run times were excessive to be able to set up LRM for the entire country with 6,000 sources and 3,000 receptors.

2. Climatological Regional Dispersion Model (CRDM)

CRDM uses assumptions similar to those in an EPA-recommended model, version 2 of the Industrial Source Complex Long Term model (ISC2LT), but incorporates terms for wet and dry deposition of gases and particles and chemical conversion of SO_2 and NO_x. CRDM employs as input climatological summaries (annual average mixing heights and joint frequency distributions of wind speed and direction) for 100 upper-air meteorological monitoring sites throughout North America.

The model uses Turner's sector-average approach, which is recommended for long-term average concentrations. Turner uses a probabilistic approach in which the frequency of occurrence of various wind and atmospheric stability conditions are used to calculate the frequency of transport in various sectors. Winds are divided into 16 cardinal wind directions (e.g., north, north-northeast, northeast, etc.). The area of each area source is determined from the area of the given county. The width of the area source is calculated as the square root of the county area.

The impact of a county on its own receptor was handled in a somewhat different manner. It was assumed that all emissions (area and point source aggregations) from the county are evenly distributed over a square with the same area as the county. The county centroid is the center of the square. The concentrations were calculated at the downwind edge of this square. It was assumed that emissions from the county are always impacting the county. A simple box model was used for each wind speed and stability category. Actual measured concentrations would be expected to be higher than those modeled with these assumptions if the monitor location was in, or generally downwind from, a portion of the county with emission densities much higher than the county average. On the other hand, concentrations would be expected to be lower if the monitor is located at the prevailing upwind edge of the county, or in an area of relatively low emission density. In addition, it should be noted that the most intensely urbanized portion of a county might be only a fraction of the county area; for example, this is the case in Los Angeles County.

The mass flux of a directly emitted primary species is dependent upon the amount of material initially emitted, as well as the amount chemically converted to a secondary pollutant, and the amount deposited by wet and dry processes during the transport time from the emission point to the downwind distance of the receptor. The mass flux of secondary pollutants is dependent upon the fraction of the primary species that is chemically converted in the atmosphere to the secondary species and the amount of the secondary species that is deposited by wet and dry deposition processes during the transport time from the stack to the downwind receptor. Dry deposition rates were selected as follows: 0.1 centimeters per second (cm/s) for all particles (including sulfates and nitrates), 0.5 cm/s for SO_2 and 1 cm/s for NO_x, gaseous nitrate, and NH_3.

Wet deposition rates were parameterized using wet deposition velocities from Yamartino. These velocities are referenced to the annual precipitation rate (P; in inches) at the given location: 0.08P for particles, 0.008P for SO_2, 0.014P for NH_3, and 0.025P for NO_x.

The pseudo-first-order rate constant for deposition was calculated from these dry and wet deposition velocities by dividing by the mixing height (mh). The deposition rates of primary and secondary species are calculated by multiplying the concentration by the applicable deposition velocity.

The vertical diffusion parameter was calculated using the subroutine from EPA's ISC2 and SCREEN2 models. Atmospheric stabilities were assumed to be C class (slightly unstable) during the day and E class (slightly stable) at night. However, if winds were greater than 6 meters per second (m/s), stability was assumed to be neutral (class D). If the selected atmospheric stabilities are more stable than actual conditions, dispersion will be under-estimated and concentrations over-predicted.

Meteorological variables were calculated from NAMER-WINDTEMP rawinsonde data obtained from the National Climatic Data Center (NCDC). Winds for each of 100 sites throughout North America were averaged for the following layers: the surface to 250 meters above ground level (m agl), 250-500 m agl, 500-1,000 m agl, 1,000-2,000 m agl, and 2,000-4,000 m agl. For each of these levels and for each of the 100 meteorological sites, a joint frequency distribution of wind direction (16 cardinal directions) and wind speeds (11 speeds in 1 m/s increments) was calculated for 1990. These distributions were calculated separately for the twice-daily soundings. The early morning soundings were assumed to be associated with the E stability category, and the late afternoon soundings were assumed to be associated with the C stability category. The appropriate wind layer for concentration calculations was determined using the centroid of the diffusing plume.

Mixing heights were determined from each sounding by calculating the virtual potential temperature. The annual average afternoon mixing heights were calculated for each of the 100 meteorological sites and were used to calculate the upper limit of vertical diffusion (h_m).

B. EMISSION INPUTS TO AIR QUALITY MODELING

NPI Version 3.0 emissions inputs to the CRDM were primarily at the county level, with four source type groupings: (1) area sources and point sources with (2) low

(3) medium and (4) high effective stack heights. There are 3,080 counties in the 48 contiguous United States. Ground-level area source emissions were estimated for each of these counties. The NPI includes a total of 61,619 point sources - too many sources to model individually. Therefore, a scheme was developed to aggregate elevated point source emissions to the county level. The effective stack height of each of these sources was calculated for an average wind speed (5 m/s). Two aggregated elevated point source groupings were made: one for sources with effective stack heights less than 250 meters, and another for sources with effective stack heights between 250 and 500 meters. There were 1,887 counties with aggregated point source emissions in the first category, and 373 counties in the second category. Sources with effective stack heights greater than 500 meters were modeled individually. There were 565 such sources. Therefore, including the ground-level area sources, there were 5,905 sources modeled in the contiguous United States (3,080 + 1,887 + 373 + 565). The S-R matrix contains a source index number which corresponds to each of the aggregate sources.

In addition to U.S. emissions, Canadian and Mexican emissions were modeled. Canadian emissions were specified by province. It was assumed that the emissions for a given province were released from an area around the largest urban area (e.g., Montreal, Quebec, and Toronto). There were 10 Canadian provinces modeled. There were 29 Mexican sources, including specific cities and states in northern Mexico. Thus, 5,944 North American sources were modeled.

For each source, primary (directly emitted) $PM_{2.5}$ and PM_{10} emissions were modeled; approximately 90 percent of primary PM_{10} and 70 percent of primary $PM_{2.5}$ emissions are estimated to result from natural and man-made fugitive dust sources. In addition to primary emissions, secondary components of $PM_{2.5}$ were estimated from the gaseous precursors. Secondary organics formed from anthropogenic and biogenic emissions were modeled using FACs; since these reactions occur within a few hours, these species were modeled similarly to primary PM. Emissions of SO_2, NO_x, and NH_3 were included in order to compute ammonium sulfate and ammonium nitrate concentrations.

The CRDM is used to develop a matrix of S-R transfer coefficients that link emissions from every county and major elevated point source in the United States, emissions from major Canadian urban areas, and emissions from the largest sources in northern Mexico, to PM air quality within every U.S. county, State centroid, Canadian province, and northern Mexican receptor. Each coefficient represents the incremental ambient air quality impact of a certain species at a given receptor from a particular area or point source. The natural source-apportionment capability of the CRDM allows for the entire matrix of air quality impacts to be expressed in terms of "normalized" increments, or more specifically, the $\mu g/m^3$ increment that occurs given each unit of emissions in $\mu g/s$. In this way, a multitude of emission scenarios by year and/or control strategy can be analyzed for their air quality impacts without requiring repetitive runs of CRDM itself. It simply requires the multiplication of an emission inventory with each S-R matrix, which yields the estimated air quality increments.

Four separate S-R matrices were developed using CRDM: (1) primary PM, appropriate for inert primary emissions of PM_{10} and $PM_{2.5}$ as well as anthropogenic and biogenic SOA (which are treated as primary inert species); (2) sulfate; (3) nitrate; and (4) NH_3. The specific size of each S-R matrix is 5,944 area and elevated points sources by 3,315 receptors

(3,081 counties, 10 Canadian provinces, 29 Mexican areas, 147 Class I Areas, and 48 State centroids). To develop these matrices, CRDM was run with each source emitting at 1 $\mu g/s$, resulting in transfer coefficients with units of s/m^3.

C. ADJUSTMENTS TO S-R MATRIX

The S-R matrix was applied to the 1996 Base Case inventory described in Chapter II to determine the model-estimated 1996 air quality for each county in the 48 contiguous States. These results were used as the basis for the normalization adjustments described below. The same types of adjustments as were made in the PM NAAQS analysis were then applied:

(1) A fugitive dust adjustment factor of 0.25 was applied to primary $PM_{2.5}$ and PM_{10} emissions from fugitive dust sources, so that the contribution of this pollutant to total $PM_{2.5}$ concentrations better matched monitoring data. In addition, emissions from natural sources were removed from the inventory prior to normalization.

(2) The annual average modeled concentrations were compared with 1993-1995 monitoring data and normalization factors were applied so that the modeled concentrations would be equivalent to the monitored values. Normalization factors were applied equivalently to all pollutant species, so that the relative contributions of the individual pollutants to total PM mass do not change. All modeled results are normalized, regardless of over-prediction or under-prediction relative to monitored values.

Monitored county normalization factors are calculated from ambient concentrations supplied by EPA for counties where data exist (Tier 1, Tier 2, and Tier 3 where the tiers are based on completeness criteria, with Tier 1 being the most complete). Because of the lack of ambient $PM_{2.5}$ monitoring data, the ambient $PM_{2.5}$ data used for this analysis is statistically developed from the 1993-1995 ambient PM_{10} data set (Pechan, 1997). The ambient concentrations are based on 1993 to 1995 PM_{10} monitoring data. The normalization factors for nonmonitored counties (Tier 4) are calculated as the average of factors determined for the 504 (Tier 1) monitored counties based on modeling region and county type (i.e., urban or nonurban). Outliers, identified as values not within two standard deviations of the average, were removed prior to the calculation of the average regional normalization factors.

D. RESULTS

Tables III-1 through III-6 show State level average annual ambient concentrations of total PM_{10}, total $PM_{2.5}$, and ammonium sulfate result for the Base Case and each emission scenario. Tables III-1 and III-2 provide the results of the floor-level MACT and above-the-floor MACT control scenarios. Tables III-3, III-4, III-5, and III-6 provide the results of the sensitivity analyses.

Table III-1
Annual Average Concentrations and Reductions due to the Floor-Level MACT Control Scenario for Selected Pollutants by State
($\mu g/m^3$)

	Base Case Scenario			Floor-Level MACT Control Scenario			Reductions Due to Floor-Level MACT		
State Name	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.3	11.9	2.2	0.56	0.13	0.02
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	0.02	-	-
Arkansas	24.4	11.5	1.9	24.3	11.5	1.9	0.15	0.04	0.01
California	32.5	11.7	1.4	32.5	11.7	1.4	-	-	-
Colorado	28.9	9.1	1.5	28.8	9.1	1.5	0.14	0.02	-
Connecticut	23.9	12.2	3.7	23.6	12.1	3.7	0.26	0.09	0.03
Delaware	29.1	16.9	4.8	28.7	16.8	4.8	0.40	0.15	0.05
DC	27.4	15.0	6.5	25.5	14.5	6.5	1.87	0.53	0.02
Florida	18.5	9.9	1.3	18.4	9.9	1.3	0.08	0.02	0.01
Georgia	27.0	13.4	1.9	26.5	13.3	1.9	0.44	0.11	0.03
Idaho	35.8	12.4	1.2	35.7	12.4	1.2	0.02	-	-
Illinois	22.6	11.4	2.5	22.4	11.3	2.4	0.17	0.06	0.03
Indiana	26.6	13.3	3.0	26.2	13.2	3.0	0.40	0.13	0.04
Iowa	17.2	8.6	1.9	17.1	8.5	1.9	0.17	0.06	0.03
Kansas	16.7	8.6	1.5	16.7	8.5	1.5	0.05	0.02	0.01
Kentucky	23.1	13.3	3.1	22.7	13.2	3.1	0.33	0.10	0.04
Louisiana	24.3	12.3	2.7	22.7	12.0	2.7	1.57	0.32	0.01
Maine	20.6	11.7	3.7	20.3	11.7	3.7	0.29	0.05	0.02
Maryland	26.3	14.7	4.4	25.8	14.5	4.3	0.48	0.18	0.04
Massachusetts	18.9	10.9	3.7	18.2	10.7	3.7	0.72	0.22	0.02
Michigan	18.5	10.6	3.0	18.0	10.5	2.9	0.49	0.16	0.07
Minnesota	18.0	9.1	2.0	17.8	9.0	1.9	0.16	0.08	0.06
Mississippi	20.1	10.5	2.1	19.8	10.4	2.0	0.28	0.06	0.01
Missouri	16.7	10.3	1.9	16.7	10.2	1.8	0.07	0.04	0.02
Montana	20.1	6.6	1.0	20.0	6.6	1.0	0.03	-	-
Nebraska	21.7	13.7	2.6	21.6	13.6	2.6	0.14	0.05	0.02
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	0.01	-	-
New Hampshire	19.1	11.3	4.8	18.8	11.2	4.8	0.31	0.08	0.02
New Jersey	29.4	16.2	4.5	29.1	16.1	4.5	0.25	0.10	0.03
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	0.01	-	-
New York	21.1	12.6	4.5	20.7	12.5	4.4	0.40	0.12	0.03
North Carolina	23.2	12.5	2.9	22.3	12.3	2.8	0.97	0.22	0.05
North Dakota	21.1	6.8	1.8	20.9	6.8	1.8	0.16	0.03	0.01
Ohio	27.1	14.9	3.8	26.8	14.7	3.7	0.32	0.12	0.07
Oklahoma	21.4	12.7	1.8	21.3	12.7	1.8	0.09	0.04	0.01
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	0.03	0.01	-
Pennsylvania	24.9	15.0	5.1	24.2	14.7	5.0	0.73	0.29	0.05
Rhode Island	23.3	12.3	4.1	22.4	12.1	4.1	0.88	0.22	0.02
South Carolina	23.1	12.0	2.5	22.4	11.8	2.5	0.78	0.17	0.04
South Dakota	25.1	7.1	1.6	24.9	7.1	1.6	0.23	0.04	0.01
Tennessee	22.7	12.0	2.6	21.8	11.8	2.6	0.98	0.20	0.03
Texas	20.7	8.7	1.4	20.7	8.7	1.4	0.06	0.01	0.01
Utah	26.4	9.8	1.4	26.4	9.8	1.4	0.01	-	-
Vermont	20.0	12.8	5.3	19.8	12.8	5.3	0.25	0.08	0.03
Virginia	23.0	13.2	3.9	22.6	13.1	3.9	0.48	0.16	0.06
Washington	26.9	10.3	1.0	26.4	10.2	1.0	0.47	0.10	0.01
West Virginia	22.4	13.5	4.1	22.0	13.4	4.0	0.32	0.11	0.06
Wisconsin	17.8	10.0	2.2	17.6	9.9	2.1	0.17	0.07	0.04
Wyoming	27.3	7.9	1.4	27.2	7.9	1.4	0.08	0.01	0.01
Average	22.68	11.2	2.4	22.37	11.1	2.3	0.32	0.09	0.03

Table III-2

Annual Average Concentrations and Reductions due to the Above-the-Floor MACT Control Scenario for Selected Pollutants by State ($\mu g/m^3$)

State Name	Base Case Scenario: Total PM_{10}	Base Case Scenario: Total $PM_{2.5}$	Base Case Scenario: Ammonium Sulfate	Above-the-Floor MACT Control Scenario: Total PM_{10}	Above-the-Floor MACT Control Scenario: Total $PM_{2.5}$	Above-the-Floor MACT Control Scenario: Ammonium Sulfate	Reductions Due to Above-the-Floor MACT: Total PM_{10}	Reductions Due to Above-the-Floor MACT: Total $PM_{2.5}$	Reductions Due to Above-the-Floor MACT: Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.3	11.9	2.2	0.61	0.15	0.02
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	0.01	-	-
Arkansas	24.4	11.5	1.9	24.2	11.4	1.9	0.22	0.06	0.02
California	32.5	11.7	1.4	32.5	11.7	1.4	0.01	-	-
Colorado	28.9	9.1	1.5	28.8	9.1	1.5	0.15	0.02	0.01
Connecticut	23.9	12.2	3.7	23.5	12.1	3.7	0.35	0.12	0.03
Delaware	29.1	16.9	4.8	28.7	16.7	4.8	0.48	0.17	0.05
DC	27.4	15.0	6.5	25.4	14.5	6.5	1.94	0.55	0.02
Florida	18.5	9.9	1.3	18.4	9.9	1.3	0.11	0.03	0.01
Georgia	27.0	13.4	1.9	26.5	13.3	1.9	0.47	0.12	0.04
Idaho	35.8	12.4	1.2	35.7	12.4	1.2	0.02	-	-
Illinois	22.8	11.4	2.5	22.4	11.3	2.4	0.19	0.07	0.04
Indiana	26.6	13.3	3.0	26.1	13.2	3.0	0.43	0.15	0.05
Iowa	17.2	8.6	1.9	17.0	8.5	1.9	0.19	0.08	0.04
Kansas	16.7	8.6	1.5	16.6	8.5	1.5	0.09	0.04	0.01
Kentucky	23.1	13.3	3.1	22.7	13.2	3.1	0.35	0.11	0.04
Louisiana	24.3	12.3	2.7	22.4	11.9	2.6	1.92	0.46	0.01
Maine	20.6	11.7	3.7	19.9	11.6	3.7	0.66	0.10	0.02
Maryland	26.3	14.7	4.4	25.8	14.5	4.3	0.54	0.20	0.05
Massachusetts	18.9	10.9	3.7	18.0	10.6	3.7	0.90	0.27	0.02
Michigan	18.5	10.6	3.0	17.9	10.4	2.9	0.53	0.18	0.08
Minnesota	18.0	9.1	2.0	17.8	9.0	1.9	0.19	0.10	0.06
Mississippi	20.1	10.5	2.1	19.7	10.4	2.0	0.33	0.08	0.02
Missouri	16.7	10.3	1.9	16.6	10.2	1.8	0.09	0.05	0.02
Montana	20.1	6.6	1.0	20.0	6.6	1.0	0.03	-	-
Nebraska	21.7	13.7	2.6	21.5	13.6	2.6	0.15	0.06	0.02
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	0.01	-	-
New Hampshire	19.1	11.3	4.8	18.7	11.2	4.8	0.48	0.12	0.03
New Jersey	29.4	16.2	4.5	29.0	16.1	4.5	0.37	0.16	0.03
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	0.02	-	-
New York	21.1	12.6	4.5	20.7	12.5	4.4	0.44	0.14	0.04
North Carolina	23.2	12.5	2.9	22.2	12.2	2.8	1.06	0.24	0.05
North Dakota	21.1	6.8	1.8	20.9	6.8	1.8	0.17	0.03	0.02
Ohio	27.1	14.9	3.8	26.8	14.7	3.7	0.34	0.14	0.08
Oklahoma	21.4	12.7	1.8	21.2	12.6	1.8	0.13	0.06	0.01
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	0.03	0.01	-
Pennsylvania	24.9	15.0	5.1	24.1	14.7	5.0	0.78	0.31	0.06
Rhode Island	23.3	12.3	4.1	22.2	12.1	4.1	1.06	0.27	0.03
South Carolina	23.1	12.0	2.5	22.3	11.8	2.5	0.87	0.20	0.04
South Dakota	25.1	7.1	1.6	24.9	7.1	1.6	0.24	0.04	0.02
Tennessee	22.7	12.0	2.6	21.7	11.7	2.6	1.02	0.22	0.03
Texas	20.7	8.7	1.4	20.6	8.7	1.4	0.10	0.03	0.01
Utah	26.4	9.8	1.4	26.4	9.8	1.4	0.01	-	-
Vermont	20.0	12.8	5.3	19.7	12.7	5.3	0.34	0.10	0.03
Virginia	23.0	13.2	3.9	22.4	13.0	3.9	0.58	0.19	0.07
Washington	26.9	10.3	1.0	26.4	10.2	1.0	0.47	0.10	0.01
West Virginia	22.4	13.5	4.1	22.0	13.4	4.0	0.35	0.12	0.06
Wisconsin	17.8	10.0	2.2	17.6	9.9	2.1	0.19	0.09	0.05
Wyoming	27.3	7.9	1.4	27.2	7.9	1.4	0.08	0.01	0.01
Average	**22.68**	**11.2**	**2.4**	**22.32**	**11.1**	**2.3**	**0.36**	**0.10**	**0.03**

Table III-3
Annual Average Concentrations and Reductions due to the Floor-Level MACT PM Only Control Scenario for Selected Pollutants by State
(μg/m³)

	Base Case Scenario			Floor-Level MACT PM Only Control Scenario			Reductions Due to Floor-Level MACT PM Only		
State Name	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.4	11.9	2.2	0.54	0.11	-
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	0.01	-	-
Arkansas	24.4	11.5	1.9	24.3	11.5	1.9	0.14	0.02	-
California	32.5	11.7	1.4	32.5	11.7	1.4	-	-	-
Colorado	28.9	9.1	1.5	28.8	9.1	1.5	0.14	0.01	-
Connecticut	23.9	12.2	3.7	23.6	12.1	3.7	0.24	0.07	-
Delaware	29.1	16.9	4.8	28.8	16.8	4.8	0.36	0.11	-
DC	27.4	15.0	6.5	25.5	14.5	6.5	1.86	0.51	-
Florida	18.5	9.9	1.3	18.5	9.9	1.3	0.07	0.01	-
Georgia	27.0	13.4	1.9	26.6	13.3	1.9	0.41	0.08	-
Idaho	35.8	12.4	1.2	35.7	12.4	1.2	0.02	-	-
Illinois	22.6	11.4	2.5	22.5	11.4	2.5	0.14	0.03	-
Indiana	26.6	13.3	3.0	26.2	13.2	3.0	0.36	0.09	-
Iowa	17.2	8.6	1.9	17.1	8.6	1.9	0.14	0.03	-
Kansas	16.7	8.6	1.5	16.7	8.5	1.5	0.05	0.01	-
Kentucky	23.1	13.3	3.1	22.8	13.3	3.1	0.30	0.07	-
Louisiana	24.3	12.3	2.7	22.7	12.0	2.7	1.56	0.31	-
Maine	20.6	11.7	3.7	20.3	11.7	3.7	0.27	0.04	-
Maryland	26.3	14.7	4.4	25.9	14.6	4.4	0.44	0.14	-
Massachusetts	18.9	10.9	3.7	18.2	10.7	3.7	0.70	0.20	-
Michigan	18.5	10.6	3.0	18.0	10.5	3.0	0.43	0.10	-
Minnesota	18.0	9.1	2.0	17.9	9.1	2.0	0.11	0.02	-
Mississippi	20.1	10.5	2.1	19.8	10.4	2.1	0.27	0.05	-
Missouri	16.7	10.3	1.9	16.7	10.2	1.9	0.05	0.02	-
Montana	20.1	6.6	1.0	20.0	6.6	1.0	0.02	-	-
Nebraska	21.7	13.7	2.6	21.6	13.7	2.6	0.12	0.04	-
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	-	-	-
New Hampshire	19.1	11.3	4.8	18.8	11.2	4.8	0.29	0.06	-
New Jersey	29.4	16.2	4.5	29.1	16.1	4.5	0.23	0.08	-
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	0.01	-	-
New York	21.1	12.6	4.5	20.7	12.5	4.5	0.38	0.10	-
North Carolina	23.2	12.5	2.9	22.3	12.3	2.9	0.92	0.17	-
North Dakota	21.1	6.8	1.8	20.9	6.8	1.8	0.14	0.02	-
Ohio	27.1	14.9	3.8	26.9	14.8	3.8	0.26	0.06	-
Oklahoma	21.4	12.7	1.8	21.3	12.7	1.8	0.08	0.03	-
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	0.03	-	-
Pennsylvania	24.9	15.0	5.1	24.2	14.8	5.1	0.69	0.25	-
Rhode Island	23.3	12.3	4.1	22.4	12.1	4.1	0.86	0.20	-
South Carolina	23.1	12.0	2.5	22.4	11.8	2.5	0.75	0.14	-
South Dakota	25.1	7.1	1.6	24.9	7.1	1.6	0.22	0.03	-
Tennessee	22.7	12.0	2.6	21.8	11.8	2.6	0.95	0.18	-
Texas	20.7	8.7	1.4	20.7	8.7	1.4	0.05	0.01	-
Utah	26.4	9.8	1.4	26.4	9.8	1.4	0.01	-	-
Vermont	20.0	12.8	5.3	19.8	12.8	5.3	0.23	0.06	-
Virginia	23.0	13.2	3.9	22.6	13.1	3.9	0.43	0.11	-
Washington	26.9	10.3	1.0	26.4	10.2	1.0	0.47	0.10	-
West Virginia	22.4	13.5	4.1	22.1	13.5	4.1	0.28	0.07	-
Wisconsin	17.8	10.0	2.2	17.7	10.0	2.2	0.13	0.03	-
Wyoming	27.3	7.9	1.4	27.2	7.9	1.4	0.07	0.01	-
Average	22.68	11.2	2.4	22.39	11.1	2.4	0.29	0.06	-

Table III-4

Annual Average Concentrations and Reductions due to the Floor-Level MACT SO_2 Only Control Scenario for Selected Pollutants by State

($\mu g/m^3$)

	Base Case Scenario			Floor-Level MACT SO_2 Only Control Scenario			Reductions Due to Floor-Level MACT SO_2 Only		
State Name	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.9	12.0	2.2	0.02	0.02	0.02
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	-	-	-
Arkansas	24.4	11.5	1.9	24.4	11.5	1.9	0.01	0.01	0.01
California	32.5	11.7	1.4	32.5	11.7	1.4	-	-	-
Colorado	28.9	9.1	1.5	28.9	9.1	1.5	-	-	-
Connecticut	23.9	12.2	3.7	23.8	12.2	3.7	0.02	0.02	0.03
Delaware	29.1	16.9	4.8	29.1	16.9	4.8	0.04	0.04	0.05
DC	27.4	15.0	6.5	27.4	15.0	6.5	0.02	0.01	0.02
Florida	18.5	9.9	1.3	18.5	9.9	1.3	0.01	0.01	0.01
Georgia	27.0	13.4	1.9	26.9	13.4	1.9	0.03	0.03	0.03
Idaho	35.8	12.4	1.2	35.8	12.4	1.2	-	-	-
Illinois	22.6	11.4	2.5	22.6	11.4	2.4	0.03	0.03	0.03
Indiana	26.6	13.3	3.0	26.5	13.3	3.0	0.04	0.04	0.04
Iowa	17.2	8.6	1.9	17.2	8.6	1.9	0.03	0.03	0.03
Kansas	16.7	8.6	1.5	16.7	8.5	1.5	0.01	0.01	0.01
Kentucky	23.1	13.3	3.1	23.0	13.3	3.1	0.04	0.03	0.04
Louisiana	24.3	12.3	2.7	24.3	12.3	2.7	0.01	0.01	0.01
Maine	20.6	11.7	3.7	20.5	11.7	3.7	0.02	0.02	0.02
Maryland	26.3	14.7	4.4	26.3	14.7	4.3	0.04	0.04	0.04
Massachusetts	18.9	10.9	3.7	18.9	10.9	3.7	0.01	0.02	0.02
Michigan	18.5	10.6	3.0	18.4	10.6	2.9	0.06	0.06	0.07
Minnesota	18.0	9.1	2.0	17.9	9.0	1.9	0.06	0.06	0.06
Mississippi	20.1	10.5	2.1	20.0	10.5	2.0	0.01	0.01	0.01
Missouri	16.7	10.3	1.9	16.7	10.2	1.8	0.02	0.02	0.02
Montana	20.1	6.6	1.0	20.1	6.6	1.0	-	-	-
Nebraska	21.7	13.7	2.6	21.7	13.7	2.6	0.02	0.02	0.02
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	-	-	-
New Hampshire	19.1	11.3	4.8	19.1	11.2	4.8	0.02	0.02	0.02
New Jersey	29.4	16.2	4.5	29.3	16.2	4.5	0.02	0.02	0.03
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	-	-	-
New York	21.1	12.6	4.5	21.1	12.6	4.4	0.02	0.02	0.03
North Carolina	23.2	12.5	2.9	23.2	12.4	2.8	0.05	0.05	0.05
North Dakota	21.1	6.8	1.8	21.0	6.8	1.8	0.01	0.01	0.01
Ohio	27.1	14.9	3.8	27.1	14.8	3.7	0.06	0.06	0.07
Oklahoma	21.4	12.7	1.8	21.4	12.7	1.8	0.01	0.01	0.01
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	-	-	-
Pennsylvania	24.9	15.0	5.1	24.8	15.0	5.0	0.04	0.04	0.05
Rhode Island	23.3	12.3	4.1	23.2	12.3	4.1	0.01	0.02	0.02
South Carolina	23.1	12.0	2.5	23.1	11.9	2.5	0.04	0.04	0.04
South Dakota	25.1	7.1	1.6	25.1	7.1	1.6	0.01	0.02	0.01
Tennessee	22.7	12.0	2.6	22.7	11.9	2.6	0.03	0.03	0.03
Texas	20.7	8.7	1.4	20.7	8.7	1.4	-	0.01	0.01
Utah	26.4	9.8	1.4	26.4	9.8	1.4	-	-	-
Vermont	20.0	12.8	5.3	20.0	12.8	5.3	0.02	0.02	0.03
Virginia	23.0	13.2	3.9	23.0	13.2	3.9	0.05	0.05	0.06
Washington	26.9	10.3	1.0	26.9	10.3	1.0	0.01	0.01	0.01
West Virginia	22.4	13.5	4.1	22.3	13.5	4.0	0.04	0.04	0.06
Wisconsin	17.8	10.0	2.2	17.7	9.9	2.1	0.04	0.04	0.04
Wyoming	27.3	7.9	1.4	27.3	7.9	1.4	0.01	0.01	0.01
Average	22.68	11.2	2.4	22.66	11.1	2.3	0.02	0.02	0.03

Table III-5

Annual Average Concentrations and Reductions due to the Above-the-Floor MACT PM Only Control Scenario for Selected Pollutants by State
(μg/m³)

	Base Case Scenario			Above-the-Floor MACT PM Only Control Scenario			Reductions Due to Above-the Floor MACT PM Only		
State Name	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.3	11.9	2.2	0.59	0.13	-
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	0.01	-	-
Arkansas	24.4	11.5	1.9	24.2	11.5	1.9	0.20	0.04	-
California	32.5	11.7	1.4	32.5	11.7	1.4	-	-	-
Colorado	28.9	9.1	1.5	28.8	9.1	1.5	0.14	0.01	-
Connecticut	23.9	12.2	3.7	23.5	12.1	3.7	0.33	0.10	-
Delaware	29.1	16.9	4.8	28.7	16.8	4.8	0.44	0.13	-
DC	27.4	15.0	6.5	25.4	14.5	6.5	1.93	0.53	-
Florida	18.5	9.9	1.3	18.4	9.9	1.3	0.10	0.02	-
Georgia	27.0	13.4	1.9	26.5	13.3	1.9	0.44	0.08	-
Idaho	35.8	12.4	1.2	35.7	12.4	1.2	0.02	-	-
Illinois	22.6	11.4	2.5	22.5	11.4	2.5	0.15	0.04	-
Indiana	26.6	13.3	3.0	26.2	13.2	3.0	0.38	0.09	-
Iowa	17.2	8.6	1.9	17.1	8.6	1.9	0.15	0.04	-
Kansas	16.7	8.6	1.5	16.6	8.5	1.5	0.08	0.03	-
Kentucky	23.1	13.3	3.1	22.8	13.3	3.1	0.31	0.07	-
Louisiana	24.3	12.3	2.7	22.4	11.9	2.7	1.91	0.45	-
Maine	20.6	11.7	3.7	19.9	11.6	3.7	0.64	0.08	-
Maryland	26.3	14.7	4.4	25.8	14.5	4.4	0.50	0.16	-
Massachusetts	18.9	10.9	3.7	18.0	10.7	3.7	0.88	0.25	-
Michigan	18.5	10.6	3.0	18.0	10.5	3.0	0.46	0.11	-
Minnesota	18.0	9.1	2.0	17.8	9.1	2.0	0.12	0.03	-
Mississippi	20.1	10.5	2.1	19.7	10.4	2.1	0.32	0.07	-
Missouri	16.7	10.3	1.9	16.7	10.2	1.9	0.07	0.03	-
Montana	20.1	6.6	1.0	20.0	6.6	1.0	0.02	-	-
Nebraska	21.7	13.7	2.6	21.6	13.7	2.6	0.13	0.04	-
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	0.01	-	-
New Hampshire	19.1	11.3	4.8	18.7	11.2	4.8	0.46	0.09	-
New Jersey	29.4	16.2	4.5	29.0	16.1	4.5	0.35	0.14	-
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	0.01	-	-
New York	21.1	12.6	4.5	20.7	12.5	4.5	0.42	0.11	-
North Carolina	23.2	12.5	2.9	22.2	12.3	2.9	1.00	0.19	-
North Dakota	21.1	6.8	1.8	20.9	6.8	1.8	0.15	0.02	-
Ohio	27.1	14.9	3.8	26.8	14.8	3.8	0.27	0.07	-
Oklahoma	21.4	12.7	1.8	21.2	12.7	1.8	0.12	0.04	-
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	0.03	-	-
Pennsylvania	24.9	15.0	5.1	24.1	14.8	5.1	0.74	0.27	-
Rhode Island	23.3	12.3	4.1	22.2	12.1	4.1	1.04	0.25	-
South Carolina	23.1	12.0	2.5	22.3	11.8	2.5	0.83	0.16	-
South Dakota	25.1	7.1	1.6	24.9	7.1	1.6	0.22	0.03	-
Tennessee	22.7	12.0	2.6	21.8	11.8	2.6	0.99	0.19	-
Texas	20.7	8.7	1.4	20.6	8.7	1.4	0.09	0.02	-
Utah	26.4	9.8	1.4	26.4	9.8	1.4	0.01	-	-
Vermont	20.0	12.8	5.3	19.7	12.8	5.3	0.31	0.08	-
Virginia	23.0	13.2	3.9	22.5	13.1	3.9	0.53	0.14	-
Washington	26.9	10.3	1.0	26.4	10.2	1.0	0.47	0.10	-
West Virginia	22.4	13.5	4.1	22.1	13.5	4.1	0.30	0.07	-
Wisconsin	17.8	10.0	2.2	17.6	10.0	2.2	0.14	0.04	-
Wyoming	27.3	7.9	1.4	27.2	7.9	1.4	0.08	0.01	-
Average	22.68	11.2	2.4	22.35	11.1	2.4	0.33	0.08	-

Table III-6

Annual Average Concentrations and Reductions due to the Above-the-Floor MACT SO_2 Only Control Scenario for Selected Pollutants by State ($\mu g/m^3$)

	Base Case Scenario			Above-the-Floor MACT SO_2 Only Control Scenario			Reductions Due to Above-the Floor MACT SO_2 Only		
State Name	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate	Total PM_{10}	Total $PM_{2.5}$	Ammonium Sulfate
Alabama	22.9	12.0	2.2	22.9	12.0	2.2	0.02	0.02	0.02
Arizona	28.5	10.2	2.7	28.5	10.2	2.7	-	-	-
Arkansas	24.4	11.5	1.9	24.4	11.5	1.9	0.02	0.02	0.02
California	32.5	11.7	1.4	32.5	11.7	1.4	-	-	-
Colorado	28.9	9.1	1.5	28.9	9.1	1.5	-	-	0.01
Connecticut	23.9	12.2	3.7	23.8	12.2	3.7	0.02	0.02	0.03
Delaware	29.1	16.9	4.8	29.1	16.9	4.8	0.05	0.04	0.05
DC	27.4	15.0	6.5	27.4	15.0	6.5	0.02	0.02	0.02
Florida	18.5	9.9	1.3	18.5	9.9	1.3	0.01	0.01	0.01
Georgia	27.0	13.4	1.9	26.9	13.4	1.9	0.04	0.03	0.04
Idaho	35.8	12.4	1.2	35.8	12.4	1.2	-	-	-
Illinois	22.6	11.4	2.5	22.6	11.4	2.4	0.03	0.03	0.04
Indiana	26.6	13.3	3.0	26.5	13.3	3.0	0.05	0.05	0.05
Iowa	17.2	8.6	1.9	17.2	8.6	1.9	0.04	0.04	0.04
Kansas	16.7	8.6	1.5	16.7	8.5	1.5	0.01	0.01	0.01
Kentucky	23.1	13.3	3.1	23.0	13.3	3.1	0.04	0.04	0.04
Louisiana	24.3	12.3	2.7	24.3	12.3	2.6	0.01	0.01	0.01
Maine	20.6	11.7	3.7	20.5	11.7	3.7	0.02	0.02	0.02
Maryland	26.3	14.7	4.4	26.3	14.7	4.3	0.04	0.04	0.05
Massachusetts	18.9	10.9	3.7	18.9	10.9	3.7	0.02	0.02	0.02
Michigan	18.5	10.6	3.0	18.4	10.5	2.9	0.07	0.07	0.08
Minnesota	18.0	9.1	2.0	17.9	9.0	1.9	0.06	0.06	0.06
Mississippi	20.1	10.5	2.1	20.0	10.5	2.0	0.02	0.02	0.02
Missouri	16.7	10.3	1.9	16.7	10.2	1.8	0.02	0.02	0.02
Montana	20.1	6.6	1.0	20.1	6.6	1.0	-	-	-
Nebraska	21.7	13.7	2.6	21.7	13.7	2.6	0.02	0.02	0.02
Nevada	28.7	9.2	1.3	28.7	9.2	1.3	-	-	-
New Hampshire	19.1	11.3	4.8	19.1	11.2	4.8	0.02	0.02	0.03
New Jersey	29.4	16.2	4.5	29.3	16.2	4.5	0.02	0.02	0.03
New Mexico	18.2	6.3	1.3	18.2	6.3	1.3	-	-	-
New York	21.1	12.6	4.5	21.1	12.6	4.4	0.03	0.03	0.04
North Carolina	23.2	12.5	2.9	23.2	12.4	2.8	0.05	0.05	0.05
North Dakota	21.1	6.8	1.8	21.0	6.8	1.8	0.01	0.01	0.02
Ohio	27.1	14.9	3.8	27.1	14.8	3.7	0.07	0.07	0.08
Oklahoma	21.4	12.7	1.8	21.4	12.7	1.8	0.01	0.01	0.01
Oregon	31.2	10.2	0.8	31.2	10.2	0.8	-	-	-
Pennsylvania	24.9	15.0	5.1	24.8	15.0	5.0	0.05	0.05	0.06
Rhode Island	23.3	12.3	4.1	23.2	12.3	4.1	0.02	0.02	0.03
South Carolina	23.1	12.0	2.5	23.1	11.9	2.5	0.04	0.04	0.04
South Dakota	25.1	7.1	1.6	25.1	7.1	1.6	0.02	0.02	0.02
Tennessee	22.7	12.0	2.6	22.7	11.9	2.6	0.03	0.03	0.03
Texas	20.7	8.7	1.4	20.7	8.7	1.4	0.01	0.01	0.01
Utah	26.4	9.8	1.4	26.4	9.8	1.4	-	-	-
Vermont	20.0	12.8	5.3	20.0	12.8	5.3	0.02	0.02	0.03
Virginia	23.0	13.2	3.9	23.0	13.2	3.9	0.06	0.06	0.07
Washington	26.9	10.3	1.0	26.9	10.3	1.0	0.01	0.01	0.01
West Virginia	22.4	13.5	4.1	22.3	13.5	4.0	0.04	0.04	0.06
Wisconsin	17.8	10.0	2.2	17.7	9.9	2.1	0.05	0.05	0.05
Wyoming	27.3	7.9	1.4	27.3	7.9	1.4	0.01	0.01	0.01
Average	22.68	11.2	2.4	22.65	11.1	2.3	0.03	0.03	0.03

CHAPTER IV
REGIONAL HAZE

The air quality concentrations for each scenario are used as inputs to a RH model that relates pollutant concentrations to RH extinction in the continental United States. A comparison between the control and Base Case scenarios represents the expected RH benefit of implementing the control defined in that scenario. The RH calculation utilizes the methodologies utilized by Pechan in support of EPA's Regional Haze Rule (Pechan, 1999). The methods used to estimate RH and the results of the analysis are summarized below.

A. DEVELOPMENT OF THE REGIONAL HAZE EXTINCTION CALCULATION METHOD

Visible light occupies a region of the electromagnetic spectrum with wavelengths between 400 and 700 nanometers (nm), corresponding closely to the majority of the radiation received by Earth from the Sun. The human eye is most sensitive to radiation in the middle of the visible region at ~550 nm. Light falling on an object is reflected and absorbed as a function of its wavelength. Light reflected from an object is transmitted through the atmosphere where its intensity is attenuated when it is scattered and absorbed by gases and particles. The sum of these scattering and absorption coefficients yields the extinction coefficient (b_{ext}) expressed in units of inverse megameters ($Mm^{-1} = 1/10^6$ m). Extinction efficiency is the amount of visible light *quenching* that coincides to a unit concentration of an atmospheric constituent. When extinction is expressed in inverse megameters (Mm^{-1}), and concentrations are expressed in $\mu g/m^3$, extinction efficiency has the units of m^2/g.

The equations and extinction efficiencies were either taken from the literature or derived from ambient measurements reported by the IMPROVE national sampling network at 43 sites between 1992 and 1995 (Sisler, 1996). This contemporary monitoring network acquires measurements of light extinction, suspended particles, and photographic documentation of views to relate objective measures of light extinction to the more subjective perceptions of human observers. IMPROVE particle concentration and optical extinction results have been reported by Malm (1992), Sisler and Malm (1994), Malm et al. (1994), and Sisler (1996). These studies have shown that changes in perception of a view are just noticeable when extinction increases or decreases by 10 to 20 percent. On the deciview (dv) scale, defined as:

$$dv = 10*\ln(b_{ext}/10\ Mm^{-1}), \qquad \text{Equation (1)}$$

a 10 or 20 percent change in light extinction corresponds to a 1 or 2 dv change, respectively.

The total atmospheric light extinction coefficient (b_{ext}) can be calculated as the summation of the individual scattering and absorption extinctions as shown in Equation 2.

$$b_{ext} = b_{Ray} + b_{sp} + b_{ag} + b_{abs}, \qquad \text{Equation (2)}$$

where:

b_{sp} = light scattering due to particles;
b_{abs} = light absorption due to particles;
b_{Ray} = light scattering due to gases;
b_{ag} = light absorption due to gases.

These extinctions can be individually estimated based on a knowledge of the atmospheric concentrations and physical properties of the light scattering or absorption species that contribute to light extinction. The discussions below detail how each of these coefficients were combined with modeled pollutant concentrations to calculate RH.

1. Light Scattering Due to Particles (b_{sp})

Light is scattered by particles suspended in the atmosphere, and the efficiency of this scattering per unit mass concentration is largest for particles with sizes comparable to the wavelength of light (~500 nm). These particles may result from natural sources, such as animal and plant organic material, wind blown dust, volcanic eruptions, and sea salt. When visibility is poor, however, most particles are found to be of manmade origin, from sources such as power plants, vehicle exhaust, biomass burning, suspended dust, and industrial activities. The most common chemical components of these particles include carbon, sulfate, nitrate, ammonium, and crustal materials (i.e., oxides of silicon, aluminum, iron, titanium, calcium, and other elements). The degree to which particles composed of these chemicals scatter light depends on their size, shape, and index of refraction (Lowenthal, et al., 1995).

In addition, atmospheric water is another important component of suspended PM. The liquid water content of ammonium nitrate, ammonium sulfate, and other soluble species increases with relative humidity, and is especially important when relative humidity exceeds 70 percent. Particles containing these compounds grow into the droplet mode as they take on liquid water, so the same concentration of sulfate or nitrate makes a much larger contribution to light extinction when humidities are high (>70 percent) than when they are low (<30 percent).

The contributions of light scattering due to particles can be estimated by summing the individual light scattering effects of fine particle ammonium sulfate, fine particle ammonium nitrate, fine particle organic carbon, fine particle soil, and coarse particle mass.[2] The individual scattering effect of each component is calculated by combining the pollutant concentration (in $\mu g/m^3$), coefficient, and extinction efficiency (m^2/g) as shown in the following equations:

[2]The concentration of coarse particle mass is defined as primary particle mass between 2.5 and 10 micrometers (i.e., PM_{10} minus $PM_{2.5}$).

fine particle amm. sulfate= C1 * [Conc. of $(NH_4)_2SO_4$] $\mu g/m^3$ * 3.0 m^2/g Equation (3)
fine particle amm. nitrate= C1 * [Conc. of NH_4NO_3] $\mu g/m^3$ * 3.0 m^2/g Equation (4)
fine particle organic carbon= [OC+SOA+BIOG] $\mu g/m^3$ * 4.0 m^2/g Equation (5)
fine particle soil= [Conc. of fine soil] $\mu g/m^3$ * 1.0 m^2/g Mm^{-1} Equation (6)
coarse particle mass = [Conc. of coarse particle mass] $\mu g/m^3$ * 0.6 m^2/g Equation (7)

where, C1 describes the annual relativity humidity effect of scattering on fine particle ammonium sulfate and ammonium nitrate. Total organic carbon is calculated as the sum of primary $PM_{2.5}$ OC, SOA, and biogenic aerosol (BIOG).

The total annual average light scattering due to particles, b_{sp}, is the sum of the individual scattering effects determined by Equations 3 through 7.

2. Light Absorption Due to Particles (b_{abs})

Elemental carbon (EC or black carbon) makes the most significant contribution to particle light absorption. High concentrations are seldom found in emissions from efficient combustion sources, though EC is abundant in motor vehicle exhaust, fires, and residential heating emissions. Additional light absorption has been shown in other studies to be caused by minerals in coarse particles, but its contribution is usually small. Theoretical considérations and measurements suggest that each $\mu g/m^3$ of black carbon contributes 8 to 12 m^2/g to extinction. Recent field measurements made at IMPROVE sites (Sisler, 1996) that compare absorption with elemental carbon concentrations show that the actual extinction efficiency of elemental carbon at IMPROVE sites is much higher. A value of 20.4 m^2/g, derived as the average of 1,600 IMPROVE measurements, is used here to better match actual measurements.

3. Light Scattering by Gases (b_{Ray})

The presence of atmospheric gases such as oxygen and nitrogen limits horizontal visual range to ~400 kilometers (km) and obscures many of the attributes of a target at less than half this distance. This Rayleigh scattering is the major component of light extinction in areas where pollution levels are low. It has a scattering coefficient of ~10 Mm^{-1}, and it can be accurately estimated from temperature and pressure measurements. Values range from 9 Mm^{-1} at high altitudes to 12 Mm^{-1} at sea level, but here it is assumed that the Rayleigh scattering coefficient is 10 Mm^{-1} at all sites as an approximation.

4. Light Absorption Due to Gases (b_{sg})

Nitrogen dioxide (NO_2) is the only gas likely to be present in Class I areas that would cause significant absorption of visible light. Each $\mu g/m^3$ of NO_2 contributes ~0.17 Mm^{-1} of extinction at ~550 nm wavelengths so NO_2 concentrations in excess of 60 $\mu g/m^3$ (30 parts per billion by volume [ppbv]) are needed to exceed Rayleigh scattering. This contribution is larger for shorter wavelengths (e.g., blue light) and smaller for longer wavelengths (e.g., red light). For this reason, plumes rich in NO_2 often appear reddish-brown because much of the yellow, blue, and purple light is absorbed. Concentrations of NO_2 were not available for use in this study, but are also expected to be lower than 30 ppbv at most pristine areas. Therefore, its concentration (and light absorption) is assumed to be negligible (i.e., zero).

B. RESULTS

Tables IV-1 through IV-7 present the average visibility extinction budgets in Mm^{-1} and dv by State for the 1996 Base Case, two control scenarios, and four sensitivity analyses. Small visibility benefits are observed in most States. Average benefits range from 0.02 dv to 0.05 dv, depending on the scenario.

Table IV-1
Base Case Scenario Average Annual Extinction Budget by State
(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)
Alabama	4.2	27.7	22.7	10.0	6.5	0.7	9.0	18.7	95.3	22.5
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9
Arkansas	3.9	22.9	23.1	10.0	7.8	1.0	7.9	18.4	90.9	22.0
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4
Colorado	2.2	9.5	8.4	10.0	11.9	0.7	4.4	16.9	61.7	18.0
Connecticut	3.6	40.9	10.2	10.0	7.0	0.8	14.8	12.6	96.2	22.5
Delaware	4.3	62.2	40.1	10.0	7.4	0.8	20.2	15.4	156.0	27.4
DC	3.0	57.7	10.7	10.0	7.4	0.6	16.9	10.0	113.3	24.3
Florida	4.7	18.4	17.1	10.0	5.2	0.5	8.8	18.5	78.6	20.4
Georgia	3.3	19.2	17.3	10.0	8.1	0.9	11.8	22.0	89.2	21.8
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.7	20.1
Illinois	4.2	31.0	27.6	10.0	6.7	1.3	8.5	11.6	96.8	22.6
Indiana	4.2	38.5	35.1	10.0	8.0	1.3	11.6	12.8	117.2	24.5
Iowa	4.1	23.7	20.1	10.0	5.2	1.1	5.5	9.9	75.5	19.8
Kansas	2.9	13.0	14.1	10.0	4.9	1.0	4.8	12.2	60.0	17.7
Kentucky	4.1	38.0	29.9	10.0	5.8	0.7	12.5	16.4	113.3	24.2
Louisiana	4.2	33.6	24.0	10.0	7.2	1.0	10.2	17.4	103.3	23.1
Maine	4.4	49.6	0.1	10.0	5.3	0.3	14.0	17.0	96.2	22.4
Maryland	3.8	50.2	27.6	10.0	7.0	0.8	16.0	13.9	125.5	25.2
Massachusetts	4.1	44.4	4.4	10.0	4.8	0.7	12.8	10.6	87.7	21.5
Michigan	4.3	38.5	21.7	10.0	4.7	0.7	8.7	12.0	96.3	22.3
Minnesota	4.3	25.6	16.6	10.0	5.3	1.1	5.7	12.4	76.7	20.2
Mississippi	4.2	26.0	21.2	10.0	5.7	0.7	7.6	16.3	87.5	21.7
Missouri	3.6	19.9	19.2	10.0	3.9	1.3	7.2	13.4	74.9	20.0
Montana	3.1	9.6	7.1	10.0	8.1	0.4	2.3	13.2	50.6	15.8
Nebraska	2.9	22.9	21.1	10.0	4.8	1.7	6.7	19.1	86.2	21.5
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4
New Hampshire	4.3	63.4	0.0	10.0	4.7	0.4	9.7	11.9	100.2	22.7
New Jersey	3.6	49.2	18.0	10.0	7.9	1.1	24.1	14.3	124.6	25.1
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4
New York	4.1	55.4	12.4	10.0	5.1	0.7	10.8	10.7	105.2	23.3
North Carolina	3.8	32.8	20.6	10.0	6.5	0.5	12.7	17.2	100.3	23.0
North Dakota	3.3	18.3	10.6	10.0	8.6	0.7	2.5	8.6	59.2	17.6
Ohio	4.2	47.3	34.5	10.0	7.4	1.0	15.6	14.1	129.8	25.6
Oklahoma	2.9	15.8	18.3	10.0	5.2	1.5	7.1	21.0	78.9	20.6
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8
Pennsylvania	3.9	59.1	21.0	10.0	5.9	0.7	13.5	14.2	124.3	25.1
Rhode Island	4.3	53.2	7.0	10.0	6.6	0.7	14.5	12.1	104.0	23.2
South Carolina	3.3	24.8	15.9	10.0	6.7	0.7	10.5	17.8	86.4	21.5
South Dakota	3.6	17.6	13.1	10.0	10.8	0.7	2.8	9.9	64.8	18.5
Tennessee	3.8	30.0	23.4	10.0	6.5	0.6	11.5	16.0	98.0	22.7
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	64.0	18.2
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2
Vermont	4.1	65.6	5.4	10.0	4.3	0.5	8.4	11.5	105.6	23.5
Virginia	3.8	45.3	23.3	10.0	5.9	0.5	12.4	15.0	112.5	24.1
Washington	4.5	13.1	11.9	10.0	9.9	0.6	7.4	20.1	72.9	19.6
West Virginia	3.6	43.3	18.1	10.0	5.3	0.5	13.3	16.8	107.4	23.7
Wisconsin	4.3	28.1	21.5	10.0	4.7	0.8	8.4	13.0	86.4	21.4
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	56.0	17.0
Average	3.6	26.5	18.7	10.0	6.9	0.9	8.7	15.5	87.2	21.2

Table IV-2

Floor-Level MACT Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State

(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.4	22.7	10.0	6.3	0.7	9.0	18.7	94.8	22.4	0.53	0.05
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.01	0.00
Arkansas	3.9	22.7	23.1	10.0	7.7	1.0	7.8	18.4	90.7	22.0	0.25	0.03
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.01	0.00
Colorado	2.2	9.4	8.4	10.0	11.8	0.7	4.4	16.9	61.6	17.9	0.11	0.02
Connecticut	3.6	40.6	10.2	10.0	6.9	0.8	14.8	12.6	95.9	22.5	0.31	0.03
Delaware	4.3	61.6	40.2	10.0	7.2	0.8	20.2	15.4	155.3	27.4	0.69	0.05
DC	3.0	57.6	10.7	10.0	6.6	0.6	16.7	9.9	112.1	24.2	1.20	0.11
Florida	4.7	18.3	17.1	10.0	5.1	0.5	8.8	18.5	78.4	20.4	0.17	0.02
Georgia	3.3	18.8	17.3	10.0	7.9	0.9	11.8	22.0	88.7	21.7	0.55	0.06
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.6	20.1	0.02	0.00
Illinois	4.2	30.6	27.6	10.0	6.7	1.3	8.5	11.5	96.3	22.5	0.44	0.05
Indiana	4.2	37.9	35.1	10.0	7.8	1.3	11.5	12.8	116.4	24.4	0.75	0.06
Iowa	4.1	23.4	20.1	10.0	5.1	1.1	5.5	9.9	75.1	19.8	0.45	0.06
Kansas	2.9	12.9	14.1	10.0	4.9	1.0	4.7	12.2	59.9	17.6	0.11	0.02
Kentucky	4.1	37.5	30.0	10.0	5.7	0.7	12.5	16.3	112.7	24.1	0.59	0.05
Louisiana	4.2	33.5	24.0	10.0	6.5	1.0	10.0	17.3	102.3	23.0	1.00	0.08
Maine	4.4	49.4	0.1	10.0	5.2	0.3	13.9	17.0	95.8	22.4	0.37	0.04
Maryland	3.8	49.7	27.7	10.0	6.8	0.8	16.0	13.9	124.8	25.2	0.63	0.05
Massachusetts	4.1	44.2	4.4	10.0	4.5	0.7	12.8	10.6	87.2	21.5	0.58	0.07
Michigan	4.3	37.6	21.8	10.0	4.5	0.7	8.7	11.9	95.2	22.2	1.00	0.10
Minnesota	4.3	24.8	16.6	10.0	5.3	1.1	5.7	12.4	75.9	20.1	0.81	0.09
Mississippi	4.2	25.9	21.2	10.0	5.6	0.7	7.5	16.3	87.1	21.6	0.32	0.04
Missouri	3.6	19.7	19.2	10.0	3.9	1.3	7.2	13.4	74.6	20.0	0.23	0.03
Montana	3.1	9.5	7.1	10.0	8.0	0.4	2.3	13.2	50.5	15.8	0.04	0.01
Nebraska	2.9	22.7	21.1	10.0	4.7	1.7	6.7	19.1	86.0	21.5	0.21	0.02
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.00	0.00
New Hampshire	4.3	63.2	0.0	10.0	4.6	0.4	9.7	11.9	99.7	22.6	0.44	0.04
New Jersey	3.6	48.9	18.1	10.0	7.8	1.1	24.1	14.3	124.3	25.1	0.32	0.03
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4	0.02	0.00
New York	4.1	55.1	12.5	10.0	4.9	0.7	10.8	10.7	104.7	23.3	0.47	0.04
North Carolina	3.8	32.2	20.7	10.0	6.0	0.5	12.6	17.2	99.2	22.9	1.02	0.10
North Dakota	3.3	18.2	10.6	10.0	8.5	0.7	2.5	8.6	59.0	17.6	0.22	0.03
Ohio	4.2	46.4	34.6	10.0	7.2	1.0	15.6	14.1	128.9	25.5	0.91	0.07
Oklahoma	2.9	15.8	18.3	10.0	5.2	1.5	7.1	21.0	78.8	20.5	0.14	0.02
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.03	0.00
Pennsylvania	3.9	58.5	21.1	10.0	5.7	0.7	13.5	14.2	123.6	25.0	0.78	0.06
Rhode Island	4.3	52.9	7.1	10.0	6.2	0.7	14.4	12.1	103.3	23.1	0.68	0.07
South Carolina	3.3	24.4	16.0	10.0	6.4	0.7	10.5	17.8	85.6	21.4	0.77	0.09
South Dakota	3.6	17.4	13.1	10.0	10.7	0.7	2.8	9.9	64.5	18.5	0.28	0.04
Tennessee	3.8	29.7	23.4	10.0	6.0	0.6	11.5	16.0	97.1	22.6	0.85	0.08
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	63.9	18.2	0.07	0.01
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.02	0.00
Vermont	4.1	65.3	5.5	10.0	4.2	0.5	8.3	11.5	105.2	23.5	0.35	0.03
Virginia	3.8	44.6	23.4	10.0	5.7	0.5	12.4	15.0	111.7	24.0	0.79	0.07
Washington	4.5	13.0	11.9	10.0	9.7	0.6	7.4	20.1	72.6	19.6	0.32	0.05
West Virginia	3.6	42.7	18.3	10.0	5.2	0.5	13.3	16.8	106.8	23.6	0.58	0.05
Wisconsin	4.3	27.5	21.5	10.0	4.6	0.8	8.4	13.0	85.8	21.4	0.65	0.08
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.08	0.01
Average	3.6	26.2	18.7	10.0	6.8	0.9	8.7	15.5	86.8	21.1	0.44	0.05

Table IV-3
Above-the-Floor MACT Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State
(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.4	22.7	10.0	6.3	0.7	9.0	18.7	94.7	22.4	0.59	0.06
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.01	0.00
Arkansas	3.9	22.7	23.1	10.0	7.7	1.0	7.8	18.4	90.6	22.0	0.32	0.04
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.01	0.00
Colorado	2.2	9.4	8.4	10.0	11.8	0.7	4.4	16.9	61.6	17.9	0.11	0.02
Connecticut	3.6	40.6	10.2	10.0	6.9	0.8	14.8	12.6	95.8	22.5	0.38	0.04
Delaware	4.3	61.5	40.2	10.0	7.2	0.8	20.2	15.4	155.2	27.4	0.79	0.06
DC	3.0	57.5	10.7	10.0	6.6	0.6	16.7	9.9	112.1	24.2	1.26	0.12
Florida	4.7	18.2	17.1	10.0	5.1	0.5	8.8	18.5	78.4	20.4	0.20	0.03
Georgia	3.3	18.8	17.3	10.0	7.9	0.9	11.8	21.9	88.6	21.7	0.59	0.07
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.6	20.1	0.03	0.00
Illinois	4.2	30.6	27.6	10.0	6.7	1.3	8.5	11.5	96.2	22.5	0.53	0.06
Indiana	4.2	37.8	35.1	10.0	7.8	1.3	11.5	12.8	116.3	24.4	0.91	0.08
Iowa	4.1	23.2	20.1	10.0	5.1	1.1	5.5	9.9	74.9	19.8	0.60	0.07
Kansas	2.9	12.9	14.1	10.0	4.9	1.0	4.7	12.2	59.9	17.6	0.15	0.02
Kentucky	4.1	37.5	30.0	10.0	5.7	0.7	12.5	16.3	112.7	24.1	0.66	0.06
Louisiana	4.2	33.5	24.0	10.0	6.3	1.0	10.0	17.3	102.0	23.0	1.25	0.11
Maine	4.4	49.4	0.1	10.0	5.0	0.3	13.9	17.0	95.6	22.4	0.64	0.07
Maryland	3.8	49.6	27.7	10.0	6.8	0.8	16.0	13.9	124.7	25.2	0.72	0.06
Massachusetts	4.1	44.2	4.5	10.0	4.4	0.7	12.7	10.6	87.0	21.5	0.71	0.08
Michigan	4.3	37.5	21.9	10.0	4.5	0.7	8.7	11.9	95.1	22.2	1.17	0.12
Minnesota	4.3	24.7	16.6	10.0	5.3	1.1	5.7	12.3	75.8	20.1	0.89	0.10
Mississippi	4.2	25.8	21.2	10.0	5.6	0.7	7.5	16.3	87.1	21.6	0.38	0.04
Missouri	3.6	19.6	19.2	10.0	3.9	1.3	7.2	13.4	74.6	20.0	0.28	0.04
Montana	3.1	9.5	7.1	10.0	8.0	0.4	2.3	13.2	50.5	15.8	0.04	0.01
Nebraska	2.9	22.7	21.1	10.0	4.7	1.7	6.7	19.1	86.0	21.5	0.25	0.03
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.01	0.00
New Hampshire	4.3	63.1	0.0	10.0	4.5	0.4	9.7	11.8	99.6	22.6	0.58	0.06
New Jersey	3.6	48.9	18.1	10.0	7.8	1.1	24.1	14.3	124.2	25.1	0.38	0.03
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.7	14.4	0.02	0.00
New York	4.1	55.0	12.5	10.0	4.9	0.7	10.8	10.7	104.6	23.3	0.53	0.05
North Carolina	3.8	32.2	20.7	10.0	6.0	0.5	12.6	17.2	99.1	22.9	1.12	0.11
North Dakota	3.3	18.1	10.6	10.0	8.5	0.7	2.5	8.6	59.0	17.6	0.25	0.04
Ohio	4.2	46.3	34.6	10.0	7.2	1.0	15.6	14.1	128.8	25.5	1.01	0.08
Oklahoma	2.9	15.7	18.3	10.0	5.2	1.5	7.1	21.0	78.8	20.5	0.18	0.02
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.03	0.00
Pennsylvania	3.9	58.4	21.1	10.0	5.6	0.7	13.5	14.2	123.5	25.0	0.86	0.07
Rhode Island	4.3	52.9	7.1	10.0	6.1	0.7	14.4	12.1	103.2	23.1	0.82	0.08
South Carolina	3.3	24.3	16.0	10.0	6.3	0.7	10.5	17.7	85.5	21.4	0.84	0.10
South Dakota	3.6	17.4	13.1	10.0	10.7	0.7	2.8	9.9	64.5	18.5	0.31	0.04
Tennessee	3.8	29.6	23.4	10.0	6.0	0.6	11.5	16.0	97.0	22.6	0.92	0.09
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	63.9	18.2	0.11	0.02
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.02	0.00
Vermont	4.1	65.2	5.5	10.0	4.2	0.5	8.3	11.5	105.2	23.5	0.44	0.04
Virginia	3.8	44.6	23.5	10.0	5.6	0.5	12.4	15.0	111.5	24.0	0.91	0.08
Washington	4.5	13.0	11.9	10.0	9.7	0.6	7.4	20.1	72.6	19.6	0.32	0.05
West Virginia	3.6	42.7	18.3	10.0	5.2	0.5	13.3	16.8	106.8	23.6	0.64	0.06
Wisconsin	4.3	27.4	21.5	10.0	4.6	0.8	8.4	13.0	85.7	21.4	0.75	0.09
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.09	0.02
Average	3.6	26.2	18.7	10.0	6.8	0.9	8.7	15.5	86.7	21.1	0.51	0.05

Table IV-4
Floor-Level MACT PM Only Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State
(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.7	22.7	10.0	6.3	0.7	9.0	18.7	95.0	22.4	0.29	0.03
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.01	0.00
Arkansas	3.9	22.9	23.1	10.0	7.7	1.0	7.8	18.4	90.8	22.0	0.08	0.01
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.00	0.00
Colorado	2.2	9.5	8.4	10.0	11.8	0.7	4.4	16.9	61.6	17.9	0.08	0.01
Connecticut	3.6	40.9	10.2	10.0	6.9	0.8	14.8	12.6	96.1	22.5	0.13	0.02
Delaware	4.3	62.2	40.1	10.0	7.2	0.8	20.2	15.4	155.8	27.4	0.17	0.02
DC	3.0	57.7	10.7	10.0	6.6	0.6	16.7	9.9	112.2	24.2	1.08	0.10
Florida	4.7	18.4	17.1	10.0	5.1	0.5	8.8	18.5	78.5	20.4	0.04	0.01
Georgia	3.3	19.2	17.3	10.0	7.9	0.9	11.8	22.0	89.0	21.7	0.23	0.03
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.7	20.1	0.01	0.00
Illinois	4.2	31.0	27.6	10.0	6.7	1.3	8.5	11.5	96.7	22.6	0.07	0.01
Indiana	4.2	38.5	35.1	10.0	7.8	1.3	11.5	12.8	117.0	24.5	0.20	0.02
Iowa	4.1	23.7	20.1	10.0	5.1	1.1	5.5	9.9	75.4	19.8	0.08	0.01
Kansas	2.9	13.0	14.1	10.0	4.9	1.0	4.7	12.2	60.0	17.7	0.03	0.00
Kentucky	4.1	38.0	29.9	10.0	5.7	0.7	12.5	16.3	113.2	24.2	0.16	0.01
Louisiana	4.2	33.6	24.0	10.0	6.5	1.0	10.0	17.3	102.4	23.0	0.88	0.07
Maine	4.4	49.6	0.1	10.0	5.2	0.3	13.9	17.0	96.0	22.4	0.15	0.02
Maryland	3.8	50.2	27.6	10.0	6.8	0.8	16.0	13.9	125.2	25.2	0.21	0.02
Massachusetts	4.1	44.4	4.4	10.0	4.5	0.7	12.8	10.6	87.4	21.5	0.38	0.04
Michigan	4.3	38.5	21.7	10.0	4.5	0.7	8.7	11.9	96.0	22.3	0.24	0.02
Minnesota	4.3	25.6	16.6	10.0	5.3	1.1	5.7	12.4	76.6	20.2	0.06	0.01
Mississippi	4.2	26.0	21.2	10.0	5.6	0.7	7.5	16.3	87.3	21.6	0.16	0.02
Missouri	3.6	19.9	19.2	10.0	3.9	1.3	7.2	13.4	74.8	20.0	0.03	0.00
Montana	3.1	9.6	7.1	10.0	8.0	0.4	2.3	13.2	50.5	15.8	0.01	0.00
Nebraska	2.9	22.9	21.1	10.0	4.7	1.7	6.7	19.1	86.2	21.5	0.06	0.01
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.00	0.00
New Hampshire	4.3	63.4	0.0	10.0	4.6	0.4	9.7	11.9	100.0	22.6	0.17	0.02
New Jersey	3.6	49.2	18.0	10.0	7.8	1.1	24.1	14.3	124.5	25.1	0.10	0.01
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4	0.01	0.00
New York	4.1	55.4	12.4	10.0	4.9	0.7	10.8	10.7	105.0	23.3	0.20	0.02
North Carolina	3.8	32.8	20.6	10.0	6.0	0.5	12.6	17.2	99.8	22.9	0.50	0.05
North Dakota	3.3	18.3	10.6	10.0	8.5	0.7	2.5	8.6	59.1	17.6	0.08	0.01
Ohio	4.2	47.3	34.5	10.0	7.2	1.0	15.6	14.1	129.7	25.5	0.14	0.01
Oklahoma	2.9	15.8	18.3	10.0	5.2	1.5	7.1	21.0	78.9	20.5	0.05	0.01
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.01	0.00
Pennsylvania	3.9	59.1	21.0	10.0	5.7	0.7	13.5	14.2	124.0	25.0	0.31	0.02
Rhode Island	4.3	53.2	7.0	10.0	6.2	0.7	14.4	12.1	103.5	23.1	0.47	0.04
South Carolina	3.3	24.8	15.9	10.0	6.4	0.7	10.5	17.8	85.9	21.4	0.41	0.05
South Dakota	3.6	17.6	13.1	10.0	10.7	0.7	2.8	9.9	64.7	18.5	0.13	0.02
Tennessee	3.8	30.0	23.4	10.0	6.0	0.6	11.5	16.0	97.4	22.6	0.52	0.05
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	64.0	18.2	0.03	0.00
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.01	0.00
Vermont	4.1	65.6	5.4	10.0	4.2	0.5	8.3	11.5	105.5	23.5	0.12	0.01
Virginia	3.8	45.3	23.3	10.0	5.7	0.5	12.4	15.0	112.2	24.1	0.22	0.02
Washington	4.5	13.1	11.9	10.0	9.7	0.6	7.4	20.1	72.7	19.6	0.24	0.04
West Virginia	3.6	43.3	18.1	10.0	5.2	0.5	13.3	16.8	107.3	23.6	0.15	0.01
Wisconsin	4.3	28.1	21.5	10.0	4.6	0.8	8.4	13.0	86.3	21.4	0.07	0.01
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.04	0.01
Average	3.6	26.5	18.7	10.0	6.8	0.9	8.7	15.5	87.1	21.2	0.16	0.02

Table IV-5

Floor-Level MACT SO_2 Only Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State

(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.4	22.7	10.0	6.5	0.7	9.0	18.7	95.0	22.4	0.28	0.03
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.00	0.00
Arkansas	3.9	22.7	23.1	10.0	7.8	1.0	7.8	18.4	90.7	22.0	0.18	0.02
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.00	0.00
Colorado	2.2	9.4	8.4	10.0	11.9	0.7	4.4	16.9	61.7	17.9	0.03	0.00
Connecticut	3.6	40.6	10.2	10.0	7.0	0.8	14.8	12.6	96.0	22.5	0.20	0.02
Delaware	4.3	61.6	40.2	10.0	7.4	0.8	20.2	15.4	155.5	27.4	0.54	0.04
DC	3.0	57.6	10.7	10.0	7.4	0.6	16.7	9.9	112.9	24.2	0.39	0.04
Florida	4.7	18.3	17.1	10.0	5.2	0.5	8.8	18.5	78.4	20.4	0.13	0.02
Georgia	3.3	18.8	17.3	10.0	8.1	0.9	11.8	22.0	88.9	21.7	0.35	0.04
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.7	20.1	0.02	0.00
Illinois	4.2	30.6	27.6	10.0	6.7	1.3	8.5	11.5	96.4	22.6	0.38	0.04
Indiana	4.2	37.9	35.1	10.0	8.0	1.3	11.5	12.8	116.6	24.5	0.59	0.05
Iowa	4.1	23.4	20.1	10.0	5.2	1.1	5.5	9.9	75.1	19.8	0.38	0.05
Kansas	2.9	12.9	14.1	10.0	4.9	1.0	4.7	12.2	59.9	17.6	0.09	0.01
Kentucky	4.1	37.5	30.0	10.0	5.8	0.7	12.5	16.3	112.9	24.2	0.45	0.04
Louisiana	4.2	33.5	24.0	10.0	7.2	1.0	10.0	17.3	103.0	23.1	0.25	0.02
Maine	4.4	49.4	0.1	10.0	5.3	0.3	13.9	17.0	98.0	22.4	0.23	0.02
Maryland	3.8	49.7	27.7	10.0	7.0	0.8	16.0	13.9	125.0	25.2	0.45	0.04
Massachusetts	4.1	44.2	4.4	10.0	4.8	0.7	12.8	10.6	87.5	21.5	0.28	0.03
Michigan	4.3	37.6	21.8	10.0	4.7	0.7	8.7	11.9	95.4	22.2	0.80	0.08
Minnesota	4.3	24.8	16.6	10.0	5.3	1.1	5.7	12.4	75.9	20.1	0.76	0.09
Mississippi	4.2	25.9	21.2	10.0	5.7	0.7	7.5	16.3	87.3	21.6	0.19	0.02
Missouri	3.6	19.7	19.2	10.0	3.9	1.3	7.2	13.4	74.6	20.0	0.21	0.03
Montana	3.1	9.5	7.1	10.0	8.1	0.4	2.3	13.2	50.5	15.8	0.02	0.01
Nebraska	2.9	22.7	21.1	10.0	4.8	1.7	6.7	19.1	86.1	21.5	0.16	0.02
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.00	0.00
New Hampshire	4.3	63.2	0.0	10.0	4.7	0.4	9.7	11.9	99.9	22.6	0.30	0.03
New Jersey	3.6	48.9	18.1	10.0	7.9	1.1	24.1	14.3	124.4	25.1	0.23	0.02
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4	0.01	0.00
New York	4.1	55.1	12.5	10.0	5.1	0.7	10.8	10.7	104.9	23.3	0.30	0.03
North Carolina	3.8	32.2	20.7	10.0	6.5	0.5	12.6	17.2	99.7	22.9	0.57	0.06
North Dakota	3.3	18.2	10.6	10.0	8.6	0.7	2.5	8.6	59.1	17.6	0.14	0.02
Ohio	4.2	46.4	34.6	10.0	7.4	1.0	15.6	14.1	129.1	25.5	0.79	0.06
Oklahoma	2.9	15.8	18.3	10.0	5.2	1.5	7.1	21.0	78.8	20.5	0.11	0.01
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.01	0.00
Pennsylvania	3.9	58.5	21.1	10.0	5.9	0.7	13.5	14.2	123.8	25.0	0.51	0.04
Rhode Island	4.3	52.9	7.1	10.0	6.6	0.7	14.4	12.1	103.7	23.1	0.29	0.03
South Carolina	3.3	24.4	16.0	10.0	6.7	0.7	10.5	17.8	86.0	21.4	0.40	0.05
South Dakota	3.6	17.4	13.1	10.0	10.8	0.7	2.8	9.9	64.7	18.5	0.17	0.02
Tennessee	3.8	29.7	23.4	10.0	6.5	0.6	11.5	16.0	97.6	22.6	0.39	0.04
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	63.9	18.2	0.05	0.01
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.01	0.00
Vermont	4.1	65.3	5.5	10.0	4.3	0.5	8.3	11.5	105.4	23.5	0.24	0.02
Virginia	3.8	44.6	23.4	10.0	5.9	0.5	12.4	15.0	111.9	24.0	0.60	0.05
Washington	4.5	13.0	11.9	10.0	9.9	0.6	7.4	20.1	72.8	19.6	0.10	0.01
West Virginia	3.6	42.7	18.3	10.0	5.3	0.5	13.3	16.8	107.0	23.6	0.45	0.04
Wisconsin	4.3	27.5	21.5	10.0	4.7	0.8	8.4	13.0	85.8	21.4	0.59	0.07
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.04	0.01
Average	3.6	26.2	18.7	10.0	6.9	0.9	8.7	15.5	88.9	21.2	0.31	0.03

Table IV-6

Above-the-Floor MACT PM Only Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State

(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.7	22.7	10.0	6.3	0.7	9.0	18.7	95.0	22.4	0.32	0.03
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.01	0.00
Arkansas	3.9	22.9	23.1	10.0	7.7	1.0	7.8	18.4	90.8	22.0	0.12	0.01
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.00	0.00
Colorado	2.2	9.5	8.4	10.0	11.8	0.7	4.4	16.9	61.6	17.9	0.08	0.01
Connecticut	3.6	40.9	10.2	10.0	6.9	0.8	14.8	12.6	96.0	22.5	0.17	0.02
Delaware	4.3	62.2	40.1	10.0	7.2	0.8	20.2	15.4	155.8	27.4	0.21	0.02
DC	3.0	57.7	10.7	10.0	6.6	0.6	16.7	9.9	112.2	24.2	1.13	0.10
Florida	4.7	18.4	17.1	10.0	5.1	0.5	8.8	18.5	78.5	20.4	0.06	0.01
Georgia	3.3	19.2	17.3	10.0	7.9	0.9	11.8	21.9	89.0	21.7	0.25	0.03
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	78.7	20.1	0.01	0.00
Illinois	4.2	31.0	27.6	10.0	6.7	1.3	8.5	11.5	96.7	22.6	0.08	0.01
Indiana	4.2	38.5	35.1	10.0	7.8	1.3	11.5	12.8	117.0	24.5	0.21	0.02
Iowa	4.1	23.7	20.1	10.0	5.1	1.1	5.5	9.9	75.4	19.8	0.09	0.01
Kansas	2.9	13.0	14.1	10.0	4.9	1.0	4.7	12.2	60.0	17.7	0.05	0.01
Kentucky	4.1	38.0	29.9	10.0	5.7	0.7	12.5	16.3	113.1	24.2	0.17	0.01
Louisiana	4.2	33.6	24.0	10.0	6.3	1.0	10.0	17.3	102.2	23.0	1.12	0.09
Maine	4.4	49.6	0.1	10.0	5.0	0.3	13.9	17.0	95.8	22.4	0.38	0.04
Maryland	3.8	50.2	27.6	10.0	6.8	0.8	16.0	13.9	125.2	25.2	0.25	0.02
Massachusetts	4.1	44.4	4.4	10.0	4.4	0.7	12.7	10.6	87.3	21.5	0.49	0.06
Michigan	4.3	38.5	21.7	10.0	4.5	0.7	8.7	11.9	96.0	22.3	0.27	0.02
Minnesota	4.3	25.6	16.6	10.0	5.3	1.1	5.7	12.3	76.6	20.2	0.08	0.01
Mississippi	4.2	26.0	21.2	10.0	5.6	0.7	7.5	16.3	87.3	21.6	0.18	0.02
Missouri	3.6	19.9	19.2	10.0	3.9	1.3	7.2	13.4	74.8	20.0	0.04	0.00
Montana	3.1	9.6	7.1	10.0	8.0	0.4	2.3	13.2	50.5	15.8	0.01	0.00
Nebraska	2.9	22.9	21.1	10.0	4.7	1.7	6.7	19.1	86.2	21.5	0.07	0.01
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.00	0.00
New Hampshire	4.3	63.4	0.0	10.0	4.5	0.4	9.7	11.8	99.9	22.6	0.27	0.03
New Jersey	3.6	49.2	18.0	10.0	7.8	1.1	24.1	14.3	124.4	25.1	0.14	0.01
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4	0.01	0.00
New York	4.1	55.4	12.4	10.0	4.9	0.7	10.8	10.7	104.9	23.3	0.22	0.02
North Carolina	3.8	32.8	20.6	10.0	6.0	0.5	12.6	17.2	99.7	22.9	0.56	0.06
North Dakota	3.3	18.3	10.6	10.0	8.5	0.7	2.5	8.6	59.1	17.6	0.09	0.01
Ohio	4.2	47.3	34.5	10.0	7.2	1.0	15.6	14.1	129.7	25.5	0.15	0.01
Oklahoma	2.9	15.8	18.3	10.0	5.2	1.5	7.1	21.0	78.9	20.5	0.07	0.01
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.01	0.00
Pennsylvania	3.9	59.1	21.0	10.0	5.6	0.7	13.5	14.2	124.0	25.0	0.33	0.03
Rhode Island	4.3	53.2	7.0	10.0	6.1	0.7	14.4	12.1	103.4	23.1	0.59	0.05
South Carolina	3.3	24.8	15.9	10.0	6.3	0.7	10.6	17.7	85.9	21.4	0.46	0.06
South Dakota	3.6	17.6	13.1	10.0	10.7	0.7	2.8	9.9	64.7	18.5	0.13	0.02
Tennessee	3.8	30.0	23.4	10.0	6.0	0.6	11.5	16.0	97.4	22.6	0.55	0.05
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	63.9	18.2	0.06	0.01
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.01	0.00
Vermont	4.1	65.6	5.4	10.0	4.2	0.5	8.3	11.6	105.4	23.5	0.17	0.02
Virginia	3.8	45.3	23.3	10.0	5.6	0.5	12.4	15.0	112.2	24.1	0.29	0.03
Washington	4.5	13.1	11.9	10.0	9.7	0.6	7.4	20.1	72.7	19.6	0.24	0.04
West Virginia	3.6	43.3	18.1	10.0	5.2	0.5	13.3	16.8	107.3	23.6	0.16	0.02
Wisconsin	4.3	28.1	21.5	10.0	4.6	0.8	8.4	13.0	86.3	21.4	0.08	0.01
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.04	0.01
Average	3.6	26.5	18.7	10.0	6.8	0.9	8.7	15.5	87.1	21.2	0.18	0.02

Table IV-7

Above-the-Floor MACT SO_2 Only Control Scenario Average Annual Extinction Budget and Reduction from Base Case Scenario by State

(Mm^{-1})

State	Relative Humidity Coefficient	Ammonium Sulfate	Ammonium Nitrate	Rayleigh Scattering	Coarse Soil	Fine Soil	Elemental Carbon	Organic Carbon	Total Extinction (Mm^{-1})	Total Extinction (dv)	Reductions in Total Extinction (Mm^{-1})	Reductions in Total Extinction (dv)
Alabama	4.2	27.4	22.7	10.0	6.5	0.7	9.0	18.7	95.0	22.4	0.32	0.03
Arizona	1.8	14.1	2.5	10.0	11.0	0.3	5.0	19.9	62.8	17.9	0.00	0.00
Arkansas	3.9	22.7	23.1	10.0	7.8	1.0	7.8	18.4	90.7	22.0	0.22	0.02
California	2.8	10.1	13.8	10.0	12.5	0.7	12.3	22.1	81.5	20.4	0.00	0.00
Colorado	2.2	9.4	8.4	10.0	11.9	0.7	4.4	16.9	61.7	17.9	0.03	0.01
Connecticut	3.6	40.6	10.2	10.0	7.0	0.8	14.8	12.6	95.9	22.5	0.24	0.03
Delaware	4.3	61.5	40.2	10.0	7.4	0.8	20.2	15.4	155.4	27.4	0.61	0.04
DC	3.0	57.5	10.7	10.0	7.4	0.6	16.7	9.9	112.9	24.2	0.42	0.04
Florida	4.7	18.2	17.1	10.0	5.2	0.5	8.8	18.5	78.4	20.4	0.16	0.02
Georgia	3.3	18.8	17.3	10.0	8.1	0.9	11.8	21.9	88.9	21.7	0.38	0.04
Idaho	2.7	9.8	9.3	10.0	14.0	1.0	5.6	27.0	76.7	20.1	0.02	0.00
Illinois	4.2	30.6	27.6	10.0	6.7	1.3	8.5	11.5	96.3	22.5	0.46	0.05
Indiana	4.2	37.8	35.1	10.0	8.0	1.3	11.5	12.8	116.5	24.4	0.74	0.06
Iowa	4.1	23.2	20.1	10.0	5.2	1.1	5.5	9.9	75.0	19.8	0.53	0.07
Kansas	2.9	12.9	14.1	10.0	4.9	1.0	4.7	12.2	59.9	17.6	0.12	0.02
Kentucky	4.1	37.5	30.0	10.0	5.8	0.7	12.5	16.3	112.8	24.1	0.51	0.04
Louisiana	4.2	33.5	24.0	10.0	7.2	1.0	10.0	17.3	102.9	23.1	0.38	0.03
Maine	4.4	49.4	0.1	10.0	5.3	0.3	13.9	17.0	95.9	22.4	0.31	0.03
Maryland	3.8	49.6	27.7	10.0	7.0	0.8	16.0	13.9	124.9	25.2	0.51	0.04
Massachusetts	4.1	44.2	4.5	10.0	4.8	0.7	12.7	10.6	87.4	21.5	0.34	0.04
Michigan	4.3	37.5	21.9	10.0	4.7	0.7	8.7	11.9	95.3	22.2	0.96	0.10
Minnesota	4.3	24.7	16.6	10.0	5.3	1.1	5.7	12.3	75.8	20.1	0.84	0.10
Mississippi	4.2	25.8	21.2	10.0	5.7	0.7	7.5	16.3	87.2	21.6	0.23	0.03
Missouri	3.6	19.6	19.2	10.0	3.9	1.3	7.2	13.4	74.6	20.0	0.26	0.03
Montana	3.1	9.5	7.1	10.0	8.1	0.4	2.3	13.2	50.5	15.8	0.03	0.01
Nebraska	2.9	22.7	21.1	10.0	4.8	1.7	6.7	19.1	86.0	21.5	0.20	0.02
Nevada	1.8	6.8	4.2	10.0	11.7	0.4	5.4	20.8	59.3	17.4	0.00	0.00
New Hampshire	4.3	63.1	0.0	10.0	4.7	0.4	9.7	11.8	99.8	22.6	0.36	0.03
New Jersey	3.6	48.9	18.1	10.0	7.9	1.1	24.1	14.3	124.3	25.1	0.26	0.02
New Mexico	2.0	7.7	4.0	10.0	7.1	0.6	2.3	12.0	43.8	14.4	0.01	0.00
New York	4.1	55.0	12.5	10.0	5.1	0.7	10.8	10.7	104.8	23.3	0.35	0.03
North Carolina	3.8	32.2	20.7	10.0	6.5	0.5	12.6	17.2	99.6	22.9	0.63	0.06
North Dakota	3.3	18.1	10.6	10.0	8.6	0.7	2.5	8.6	59.0	17.6	0.17	0.03
Ohio	4.2	46.3	34.6	10.0	7.4	1.0	15.6	14.1	129.0	25.5	0.89	0.07
Oklahoma	2.9	15.7	18.3	10.0	5.2	1.5	7.1	21.0	78.8	20.5	0.14	0.02
Oregon	4.6	10.8	11.7	10.0	12.6	0.9	7.0	22.1	75.2	19.8	0.02	0.00
Pennsylvania	3.9	58.4	21.1	10.0	5.9	0.7	13.5	14.2	123.8	25.0	0.57	0.05
Rhode Island	4.3	52.9	7.1	10.0	6.6	0.7	14.4	12.1	103.6	23.1	0.35	0.03
South Carolina	3.3	24.3	16.0	10.0	6.7	0.7	10.6	17.7	85.9	21.4	0.44	0.05
South Dakota	3.6	17.4	13.1	10.0	10.8	0.7	2.8	9.9	64.6	18.5	0.19	0.03
Tennessee	3.8	29.6	23.4	10.0	6.5	0.6	11.5	16.0	97.5	22.6	0.44	0.04
Texas	3.0	12.8	13.4	10.0	7.2	1.0	5.4	14.2	63.9	18.2	0.07	0.01
Utah	2.4	10.3	7.4	10.0	9.9	0.5	4.6	20.8	63.4	18.2	0.01	0.00
Vermont	4.1	65.2	5.5	10.0	4.3	0.5	8.3	11.5	105.3	23.5	0.30	0.03
Virginia	3.8	44.6	23.5	10.0	5.9	0.5	12.4	15.0	111.8	24.0	0.68	0.06
Washington	4.5	13.0	11.9	10.0	9.9	0.6	7.4	20.1	72.8	19.6	0.10	0.01
West Virginia	3.6	42.7	18.3	10.0	5.3	0.5	13.3	16.8	106.9	23.6	0.50	0.05
Wisconsin	4.3	27.4	21.5	10.0	4.7	0.8	8.4	13.0	85.7	21.4	0.68	0.08
Wyoming	2.3	9.4	6.9	10.0	11.6	0.7	2.3	15.1	55.9	17.0	0.04	0.01
Average	3.6	26.2	18.7	10.0	6.9	0.9	8.7	15.5	86.9	21.2	0.36	0.04

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